30. MTI REPETITION RATE TRIGGER AMPLIFIER (Fig 27)

a. This assembly of the signal comparator unit develops the repetition rate triggers for gated MTI or normal radar operation. Also, bipolar delayed and nondelayed video signals are developed from the incoming bipolar phase-detected video signals. A major portion of the circuits operate at a frequency of 9 mc, this frequency being the mean operating frequency of the 2, 500-microsecond delay line. To obtain operation at this frequency, a 9-mc carrier signal is generated. The incoming video is introduced by amplitude modulation of this carrier signal. In order to time-balance received signals of adjacent pulses, circuits which delay received signals are also made part of the timing circuit. The timing circuit then generates triggers whose timing is exactly equivalent to the delay required to achieve accurate time balance. As triggers are developed at zero time, there is little or no interference between the two signals.

b. The 2, 500-microsecond delay line W2350 is the main delay element and hence the main controlling element of pulse timing. Other circuits which add delay and are necessary to circuit function are included in both the delayed signal and the timing circuits. These circuits are the 9-mc oscillator (V1355) and amplifiers (V1356 and V1357), and the delay amplifier (V1301-V1306). A 1.9-microsecond delay line W2351 is used in the signal output of the delay amplifier to make up for delay in the timing circuit, which is not common to the delay signal circuit, and also to make up for delay in the nondelay signal circuit.

c. In order to develop triggers using the delay line, which operates at 9 mc, keying of the 9-mc oscillator is necessary. A free-running multivibrator is used to turn the 9-mc oscillator on. The multivibrator period is adjusted to turn the 9-mc oscillator off before the initial "on" impulse has reached the end of the delay line. (The delay line time is 2, 500 microseconds; the multivibrator is adjusted to approximately 2, 400 microseconds.) After the 9-mc signal has passed through the delay amplifier, the demodulated signal (actually a 2, 400-microsecond gate) is differentiated. The trigger signal, which is the delayed on impulse, then turns the multivibrator on. The on signal then produces the next on period, and so on. Therefore, the timing of the complete loop controls the operation period. As information from the multivibrator is used to develop triggers for the modulator, the pulse repetition is then set by the period of the timing circuit loop.

d. The circuits of the MTI repetition rate trigger amplifier consist of 9-mc modulated oscillator V1355, two 9-mc amplifiers V1356 and V1357, gate trigger amplifiers V1350 and V1351, carrier gate multivibrator V1353B and V1354, trigger generator V1353A, and trigger output amplifier V1352.

e. The carrier gate multivibrator uses the cathode, control grid, and screen grids of V1354 for one triode section of the multivibrator, V1353B being the other multivibrator triode section. Otherwise, the operation of the multivibrator is conventional, with R1365 controlling the operating period by adjusting the V1354 grid circuit time constant. The plate circuit of V1354 contains the 9-mc oscillator inductance, which is capacity-coupled (C1368) to grid 1 of the modulated oscillator, V1355. The oscillator section of V1355, besides grid 1, consists of the screen grid and the cathode. Negative resistance to sustain oscillations is obtained by making the cathode of V1355 reactive by the choice of the proper value of

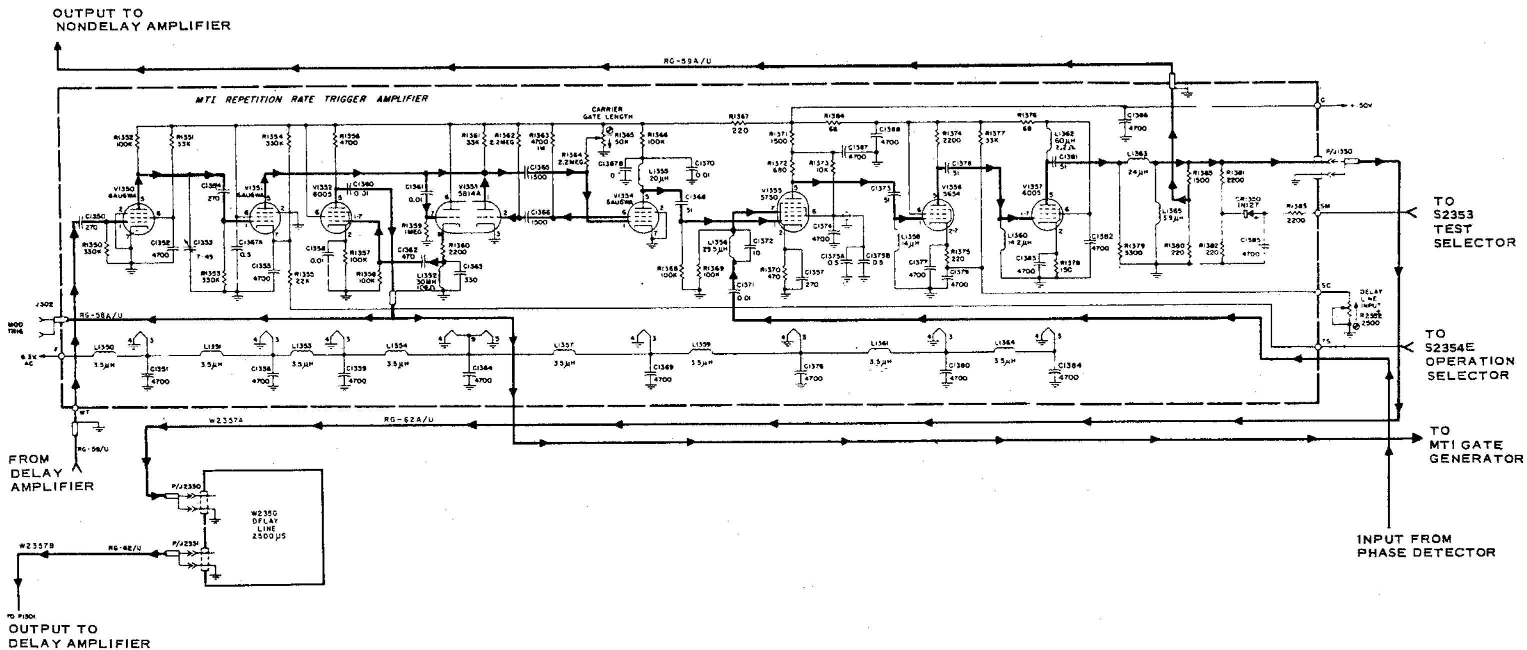

Figure 27. MTI repetition rate trigger amplifier.

cathode capacitor C1357. Actually the circuit is the equivalent of a grounded-plate Colpitts oscillator. During the multivibrator off period, V1354 is conducting heavily, which effectively grounds the grid end of the oscillator coil. When the multivibrator is turned on, the plate current of V1354 is cut off, and therefore, the oscillator section of V1355 will operate and produce a 9-mc signal. The frequency-determining portion of the oscillator consists of L1355, the plate-to-ground capacitance of V1354, the grid-to-ground capacitance of V1355, and stray circuit reactances. The phase-detected video signals from the 60-mc amplifier are fed to grid 3 of V1355. Thus, the 9-mc signals appearing in the plate circuit of V1355 are amplitude-modulated by the phase-detected video signals. The degree of modulation is set at approximately 30 percent. A 9-mc trap is included in the 3 grid circuit of V1355 to prevent 9-mc signals from getting back into the 60-mc phase detector circuit.

f. The modulated 9-mc signals then are amplified by V1356 and V1357. Gain is controlled by DELAY LINE INPUT control R2352, which is part of a voltage divider circuit (R2352 and R1377) and controls the cathode bias of V1356. Inductances L1363 and L1365, in the output circuit of V1357, lower the impedance of the signal circuit to feed signal voltage to the 2, 500-microsecond delay line through a 90-ohm cable. The output signal voltage to the nondelay amplifier is attenuated 10 db so that signal input voltages to the delay and nondelay amplifiers are more nearly equal. Voltage from the output circuit of V1357 is also rectified by CR1350 to develop dc across capacitor C1385, the dc being used in the metering circuit to provide an indication of output level. As indicated above, the carrier gate multivibrator V1353B and V1354 is triggered on by a demodulated signal from the output of the delay amplifier. This output consists of a negative gate which may be modulated by either positive or negative video signals.

g. The output of the delay amplifier is fed to the grid of V1350. The gate signal is differentiated across the input coupling capacitor so that the leading edge of the gate produces a negative trigger signal at the grid of V1350. To limit the static tube current, V1350 is operated at zero bias and with relatively low screen voltage. By operating V1350 at zero bias, the input circuit is dc-restored. Also, the use of zero bias makes V1350 sensitive to only negative input signals. The positive differentiated gate signal at the plate of V1350 is integrated by the use of a relatively high value of plate load resistor R1352, the shunt capacitances of C1353, and the associated circuit and tube capacitances. This provides the leading edge of the trigger signal with a slope of approximately 3 microseconds. C1353 is variable to permit a slope adjustment.

h. The positive signal is then applied to the grid of the cutoff amplifier, V1351. V1351 is operated with bias which is adjustable from 1-1/2 to 6 times cutoff. The bias, obtained in the cathode circuit by a voltage divider, is adjusted by the MTI BALANCE control, either R2356 in the signal comparator or R2618 in the indicator. As the amplitude of the signal at the grid of V1350 is approximately 50 volts, V1351 will almost instantly reach full conduction after the cutoff bias is overcome by the input signal. Therefore, as the input signal has a definite slope, the MTI BALANCE control (R2356 or R2618), by adjusting the initial bias, provides a timing adjustment of the trigger signal developed in the plate of V1351. As the signals from V1351 trigger the carrier gate multivibrator V1353B and V1354, the trigger timing adjustment affects the timing circuit period (fig 28). The multivibrator trigger circuits of V1350 and V1351 add time to the pulse interval. Since this added delay time is not included in the delayed signal circuit, which consists of the quartz delay line W2350 and the delay amplifier, the delayed signal circuit would be short by the amount of time consumed

in the multivibrator trigger circuits. To make the delayed signal circuit time equal to the pulse interval time, a 1.9-microsecond delay line, W2351, is added in the output circuit between the delay amplifier and the video balancer and amplifier. This 1.9-microsecond delay is a value which permits the pulse interval to be adjusted by MTI BALANCE control R2356 in the trigger circuit, both above and below the total delayed signal circuit time. Amplifier V1351 is dc-coupled to the multivibrator and shares plate load resistor R1361 with V1353B. It can therefore be seen that the negative trigger signals will trip the multivibrator only when the multivibrator is off, the off period starting approximately 2, 400 microseconds after the multivibrator is triggered.

i. To develop triggers for the modulator, the gating signal is applied to the grid of shocked oscillator V1353A. V1353A is essentially a cathode follower having a tuned circuit L1352 and C1363 in series with the cathode circuit. The grid circuit of trigger generator, V1352, is connected across the tuned circuit, with C1362 providing dc blocking. V1352 is operated with near-cutoff cathode bias. During the 100-microsecond off period of the carrier gate, V1353A is at maximum conduction, with its cathode current flowing through L1352. This places the ungrounded end of L1352 and C1363 at a fixed positive voltage. When the gate is triggered, V1353A is cut off and L1352-C1363 starts into oscillation. As the first half-cycle of oscillation is negative, little effect is produced on V1352. When the oscillation swings into its first positive half-cycle, V1352 will conduct and produce a trigger in its plate circuit. The loading across the tuned circuit produces a steep decrement in the oscillation, and only a small trigger is produced on the following positive swing of the tuned circuit. This trigger is removed by clipping in the trigger input circuit of the modulator. The timing of L1352 and C1363 is such that the initial trigger is developed 10 microseconds after the carrier gate is turned on. The chief purpose of this 10-microsecond delay of the trigger is to prevent the false moving target, due to the beginning of the 9-mc carrier, from appearing on the PPI and A-scopes. This disturbance must be over before the indicator sweep begins. Delaying the trigger by this amount also allows time for any reflections left in the delay line from the initial impulse of the carrier gate to die out. This removes any possibility of interference in the delay line with early-received signals. Also, the 10-microsecond delay insures that the carrier gate is triggered by the leading edge of the delayed carrier gate with no influence from received signals.

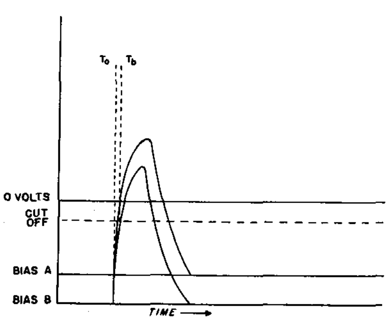

Figure 28. Input signal at V1351.

31. EXTERNAL TRIGGER CIRCUITS

a. To develop triggers for the transmitter, the output from the multivibrator is applied to the grid of the external trigger generator (V1353B) which is a shock-excited oscillator. The output of the shock-excited oscillator is then applied to trigger amplifier (V1352), which develops the external trigger for the modulator and the MTI gate generator.

b. V1353B is a shock-excited 50-kc ringing oscillator with a tuned circuit, L1352 and C1363, in the cathode. During the 100-microsecond off period of the multivibrator, V1353B is at maximum conduction because the positive portion of the carrier gate is being applied to its grid. There will be no output from the ringing oscillator at this time. When the multivibrator is synchronized, the negative portion of the carrier gate cuts off V1353B, and the tank circuit starts oscillating (fig 25(8)). Since the tank is located in the cathode circuit, the first alternation is of a negative polarity. The frequency of these oscillations is 50 kc, giving a total period of 20 microseconds for one complete cycle. This train of damped oscillations is coupled through an RC network, R1358 and C1362, to the grid of V1352.

c. The trigger amplifier (V1352) is operating near cutoff due to the large value of the cathode resistance. Any negative signal applied to the grid completely cuts off the tube, and the signal is not amplified. However, a positive signal causes the tube to increase in conduction, and appears as a negative signal at the plate. Since the alternation of the input signal is negative, it does not appear in the output; there will be no output until the first positive alternation is seen at the grid. The output will be a negative pulse (fig 25(9)), which is sent to the modulator as the external trigger. The external trigger is cabled from J302 at the signal comparator to J152 at the modulator.

d. As the trigger amplifier produces no output until the first positive alternation from the ringing oscillator, there is a slight delay in the production fo the external trigger. This delay, equal to the period of the negative alternation of 10 microseconds, allows the 9-mc oscillator to start before the transmitter is triggered. The purpose of the 10-microsecond delay of the external trigger is to prevent noise from appearing on the PPI and the A-scope. The noise disturbance caused by the distortion and attenuation in the delay tank while a wave motion is started passes through the comparison point 10 microseconds before the starting of the indicator sweeps; therefore, this distrubance is never seen in the scopes.

32. 9-MC GATED OSCILLATOR V1355

a. The 9-mc oscillator, V1355, generates the frequency which acts as a carrier for the video. The oscillator elements are the cathode, grid, and screen grid of the tube; the tank circuit composed of L1355; plate-to-ground capacitance of V1354; and the interelectrode capacitance from grid to cathode and screen grid to cathode of V1355. This type of oscillator is equivalent to a grounded plate Colpitts oscillator. Figure 29 is a simplified drawing of a Colpitts oscillator with the components numbered in reference to the 9-mc oscillator, V1355. The grid-to-cathode capacitance and the screen grid-to-cathode capacitance form the divider network, with the latter being used as the feedback path that sustains oscillation. The cathode of the oscillator is connected between these two interelectrode capacities.

b. The coil of the tank circuit L1355 is located in the plate of V1354 so that the oscillator may be turned off and on. When the V1354 section of the timer multivibrator conducts, it

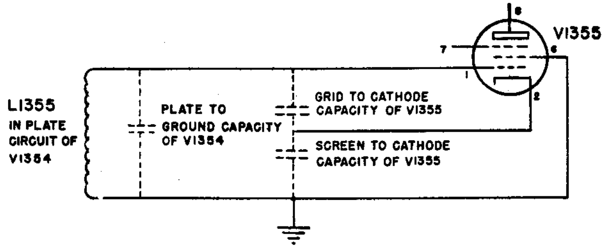

Figure 29. Colpitts oscillator.

effectively places a shunt resistance in the circuit, dampening oscillations. V1354 is cut off for 2,400 microseconds, which allows the 9-mc oscillator to function during that period. Then the oscillator is cut off for 100 microseconds by the conduction of V1354. The 9-mc signal, present for 2,400 microseconds and absent for 100 microseconds, is later detected and used to trigger the same circuits by a closed loop arrangement.

c. The bipolar video from the phase detector is applied to the suppressor grid, pin 7, of the oscillator through a 9-mc trap, consisting of L1356 and C1372. The trap is a tuned 9-mc parallel tank which keeps the 9-mc signals from entering the phase detector. C1368 and R1368 form a grid leak bias network for the oscillator; R1370 is the cathode resistor with its bypass capacitor, C1357.

d. Cathode current of V1355 is the sum of the screen grid and plate current. The screen grid, pin 6, acts as the plate of the oscillator and variations in the current at the screen grid will feed back to sustain oscillations. This current is subtracted from the actual plate current, pin 5, giving inverse variations to it. The coupling from the oscillator section to the plate is in the electron stream through the tube. Thus, the oscillating source is kept at maximum isolation.

e. The amplitude of oscillations out of the 9-mc oscillator is held constant by means of a constant plate and screen grid voltage. On the application of bipolar video, the signal grid either increases or decreases the plate current, depending upon the video polarity. A positive video pulse gives greater modulation and a negative pulse gives less modulation. Due to the plate current variations of V1355, the output appears as an amplitude modulated carrier. The modulations are impressed at approximately 30 percent maximum, so that the effect of turning the oscillator on and off will not be experienced as it would be in the case of 100 percent modulation.

f. The 9-mc modulated signal output of V1355 is applied through C1373 to the grid of the voltage amplifier, V1356. The amplification is necessary so the signal will not be completely attenuated within the quartz delay line. L1358, along with the stray and distributive capacitance, is tuned to 9 mc for maximum signal development. In the cathode circuit, resistor R1375 and variable resistor R2352 are bypassed by capacitors C1377 and C1379. By changing the resistance of the DELAY LINE INPUT (R2352) the cathode bias can be varied from 0 to 10.5 volts, which changes the amplitude of the output signal. The output from the 9-mc oscillator is measured by the TEST METER (M2350) with the TEST SELECTOR switch

set to the DELAY LINE INPUT position. The output reading should be at the red line on the test meter, and if low or high readings exist, the discrepancy can normally be corrected by adjusting R2352.

g. The output of V1356 is applied through C1378 to the grid of V1357, which builds the modulated signal to sufficient power so that it can excite the crystal in the delay line. L1360, along with its stray and distributive capacitance, is tuned to 9 mc. L1362 in the plate circuit is used because its resonant frequency is 9 mc and has its largest impedance at this frequency, giving maximum amplification to the 9-mc carrier frequency. The output signal is coupled through C1381 to the output network of V1357 which channels the signal to the nondelay amplifiers, quartz delay line, and TEST METER M2350.

h. In the output network, L1363 and L1365 are used to match the impedance of the 72-ohm transmission cable that carries the signal from J1350 to the quartz delay line. The output to the nondelay channel is attenuated 10 db by R1385 and R1380 and cabled into J2301. The output to the test meter is filtered for dc current by R1381, R1382, C1385, and CR1350, and the dc level of the 9-mc oscillator output is monitored in the DELAY LINE INPUT position. Effectively, the meter indicates the proper operation of the 9-mc oscillator and can be adjusted to read red-line on the meter by varying R2352, which changes the bias of V1356 and controls the output amplitude.

33. 2, 500-MICROSECOND DELAY LINE (Fig 30)

a. The long delay (2, 500 microseconds) and wide bandwidth (3 mc) of the delay line are obtained by making use of the relatively slow velocity of transmission of mechanical vibrations through solids. The ultrasonic delay line achieves its delay by converting electrical energy into acoustical energy (mechanical vibrations) and passing the vibrations through a solid medium such as fused quartz. The velocity of propagation of acoustical energy in fused quartz is approximately 151, 000 times slower than electrical energy through a wire.

b. The 9-mc input signal from the repetition rate amplifier is applied to an electrode which is bonded to a piezoelectric crystal. The crystal in turn is bonded to the fused quartz with a conducting material in between to serve as a ground. (This crystal is the transducer shown in figure 30.) Through the piezoelectric effect, the electrical signals are converted into acoustical energy (mechanical vibrations). The crystal is tightly bonded to the quartz and therefore sets up mechanical vibrations that travel through the quartz and arrive at the output transducer, which is exactly the same in construction as the input transducer. Here, however, the mechanical vibrations are converted back into electrical energy.

c. There is little or no distortion of the input signal in the conversion to mechanical and back to electrical energy. The delay time is 2, 500 microseconds, plus or minus 10 microseconds; the acoustic bandwidth is 3 mc; and the attenuation is less than 60 db. (The attenuation of spurious signals is at least 30 db below the desired signal.) The transmitting medium of the line consists of fused quartz which has effectively 31 paths of mechanical vibration. The quartz and the transducers are hermetically sealed into a plated case measuring approximately 16 inches in diameter by 1-1/8 inch thick. The input and output cables are connected to female BNC connectors, which are hermetically sealed to the case and electrically connected to the input and output transducers. There are no heater circuits

associated with the line. It is designed to operate over a temperature range of from -45 to +75 degrees C (-49 to +167 degrees F). The case is mounted in the bottom of the signal comparator inner case.

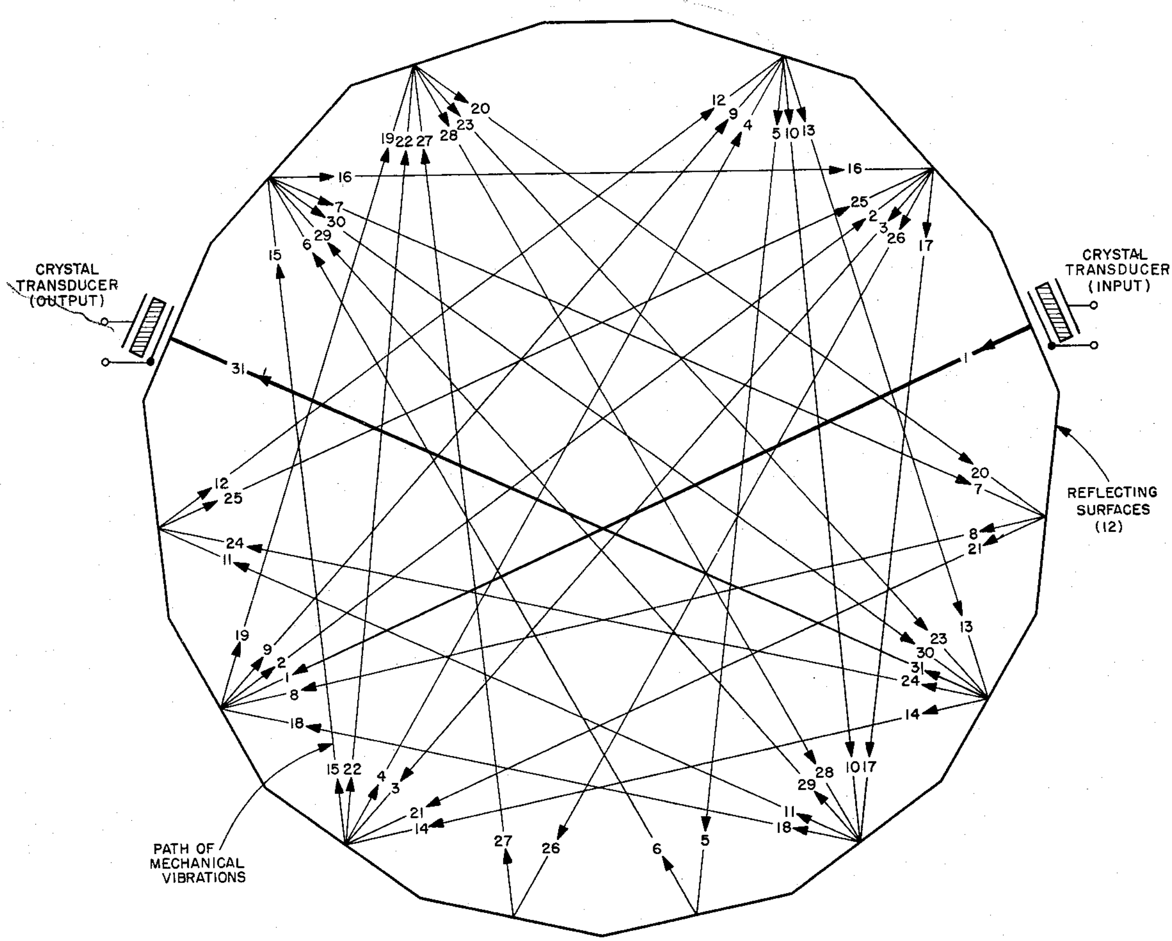

Figure 30. Delay network details.

Section IV. TROUBLESHOOTING

34. TIMER TROUBLESHOOTING

a. Any trouble in the timer circuit is indicated by either faulty or no gated MTI operation. Troubles in the timer may be grouped into two general classifications.

(1) Troubles that make gated MTI operation impossible because of the external trigger absence.

(2) Troubles that produce faulty gated MTI operation due to the absence of a synchronizing signal to the multivibrator.

Troubles in the first category are easily recognizable since the transmitter cannot be energized due to the absence of the EXTERNAL trigger. The troubles that produce faulty gated MTI operation are not so obvious, but are usually indicated in the MTI tuning procedure.

b. If the transmitter does not operate with TRIGGER switch S152 set to EXTERNAL, the output of the signal comparator at J302 should be checked to determine if an external trigger is being produced in that unit. If there is no trigger output at J302, the three stages that could possibly cause this trouble are V1352, V1353A and B, and V1354.

c. If the multivibrator is not synchronized, gated MTI operation will be very erratic. Should this trouble occur, the fixed targets could not be canceled at the comparison point and would be observed on the indicator screens. V1350 and V1351 are the two stages in the trigger circuit that cause the loss of the synchronizing signal. However, as the signal comes from the delay channel, a trouble in either the delay line (W2350) or the delay amplifiers could cause the loss of the synchronizing signal.

35. TEST METER M2350

a. 9-mc oscillator. The proper use of the TEST METER (M2350) is a guide for troubleshooting the 9-mc oscillator. The meter, when set to the DELAY LINE INPUT position, reads the filtered output of the oscillator channel signal. If no reading is possible after adjusting R2352, the trouble could be the faulty stages of V1355, V1356, or V1357.

b. Pulse delay network W2350 check.

(1) Complete failure of the delay network is unlikely unless the signal comparator is subject to severe shock, thus causing damage to the crystal or the transducers. With normal handling and use, the network attenuation is not likely to increase.

(2) If the attenuation of W2350 changes, it will become necessary to change the setting of the AMPL BALANCE control (R2354) in order to obtain a red-line reading of the signal comparator test meter M2350. The delay network is usable as long as R2354 can be adjusted for a red-line deflection.

(3) The procedure for checking W2350 consists of substituting an attenuator, Z2350, which has the loss (approximatley 60 db) that the delay network would have before it becomes unusable.

(4) The position of the AMPL BALANCE control R2354 should be approximately in the middle of its range for a red-line deflection of M2350 if the delay network and the delay amplifier circuits are normal. If the adjustment of R2354 is almost fully clockwise or if, with R2354 in the full-clockwise position, the deflection of M2350 is below the red line, either the delay network or the delay amplifier circuit may be at fault.

c. From the output network, the signal is channeled to the nondelay channel, delay channel, and TEST METER M2350.

d. The signal input to the quartz delay line activates a crystal which changes electrical variations into mechanical vibrations. These mechanical waves take 2, 500 microseconds before they reach the output end of the quartz delay line and are attenuated 60 db.

37. QUESTIONS

a. What elements of V1355 compose the 9-mc oscillator?

b. What is the purpose of L1356 and C1372?

c. Why is L1355, the tank coil of the 9-mc oscillator, in the plate circuit of V1354?

d. What is the advantage of using electronic coupling in the oscillator section?

e. What is the purpose of V1356 and V1357?

f. The output network of the 9-mc oscillator circuitry has three outputs. Where do they go?

g. In what position of test meter M2350 will the output of the 9-mc oscillator be monitored?

h. What are the tube designations for the multivibrator in the timer? What type of multivibrator is it?

i. How does the multivibrator control the operation of the 9-mc oscillator?

j. The input signal to the pulse amplifier, V1350, is the output of which channel?

k. Why do only negative pulses appear at the output of V1350, as seen at its plate?

l. What is the bias on V1351 with the MTI BALANCE control (R2356) set to midposition?

m. What is the effect on the length of time that the 9-mc oscillator is cut off, if the CARRIER GATE LENGTH control (R1365) is increased in resistance?

n. During the off period of the multivibrator, will V1353B be cut off or conducting?

o. Since the input is a train of damped oscillations, why is the output of V1352 only a negative pulse?

(5) When the test attenuator, Z2350, is substituted for W2350, the delay amplifier circuit is at fault if the same condition exists. However, if the adjustment of R2354 is in mid-position for a red-line adjustment, the delay network is at fault and replacement will be necessary.

(6) An approximation of the degree of attenuation can be obtained by adjusting for red-line readings on M2350 with the test attenuator in place. Then connect the delay network, W2350, back into the circuit. If the deflection of M2350 is half the red-line deflection, the attenuation of W2350 is approximately 6 db below that of Z2350, or approximately 66 db. If M2350 shows one quarter of the red-line deflection, the attenuation of W2350 is approximately 12 db below 60 db, or 72 db. It should be remembered that this is only an approximation and that the delay network should work satisfactorily as long as a red-line deflection can be obtained.

(7) To connect the test attenuator, proceed as follows:

(a) With the equipment shut down, pull out the signal comparator chassis as far as the chassis stops.

Caution: If at any time it is necessary to pull the chassis out beyond its stops, first disconnect the delay network cables from the underside of the chassis at J1301 and J1350. Otherwise, damage to the cables and/or cable fittings may result.

(b) Disconnect the two coaxial cables attached to the delay network at J2350 and J2351.

(c) Connect the test attenuator Z2350 to P2350 and P2351. Z2350 is found mounted in clips at the rear and on top of the signal comparator chassis.

(d) Close the chassis and make checks.

(e) Return Z2350 to its mount and reconnect W2350 when the checks are completed.

Section V. SUMMARY AND QUESTIONS

36. SUMMARY

a. The timer circuits (V1350, V1351, V1352, V1353, and V1354) insure an accurate pulse repetition time to obtain complete cancellation of fixed targets. The heart of the timer is a free-running multivibrator synchronized by its own output that has passed through the delay channel. To accurately control the prf, the transient time of the timer feedback loop is made variable by the CARRIER GATE LENGTH control (R1365) and the MTI BALANCE control (R2356 or R2618). The trigger is delayed 10 microseconds in respect to the start of the 9-mc oscillator for stability in the delay channel.

b. The negative or positive video pulses from the phase detector are applied through the 9-mc trap to the suppressor grid, pin 7, or the oscillator tube. These pulses modulate the 9-mc signal and are electronically coupled out of the oscillator tube, V1355. The modulated 9-mc carrier is amplified through two stages of amplification and then applied to an output network.

c. From the output network, the signal is channeled to the nondelay channel, delay channel, and TEST METER M2350.

d. The signal input to the quartz delay line activates a crystal which changes electrical variations into mechanical vibrations. These mechanical waves take 2, 500 microseconds before they reach the output end of the quartz delay line and are attenuated 60 db.

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g. In what position of test meter M2350 will the output of the 9-mc oscillator be monitored?

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k. Why do only negative pulses appear at the output of V1350, as seen at its plate?

l. What is the bias on V1351 with the MTI BALANCE control (R2356) set to midposition?

m. What is the effect on the length of time that the 9-mc oscillator is cut off, if the CARRIER GATE LENGTH control (R1365) is increased in resistance?

n. During the off period of the multivibrator, will V1353B be cut off or conducting?

o. Since the input is a train of damped oscillations, why is the output of V1352 only a negative pulse?

CHAPTER 5

DELAY AND NONDELAY CHANNELS AND MTI AUTOMATIC GAIN CONTROL CIRCUITS

Section I. INTRODUCTION

38. GENERAL

a. The delay and nondelay amplifier channels amplify the 9-mc amplitude modulated carrier and detect both moving and fixed target video signals from the carrier. These video signals are applied to a common comparison point, where cancellation of fixed targets and detection of moving targets is accomplished.

b. The two amplifier channels increase the amplitude of the 9-mc modulated carrier before detection. The amplitude is kept at equal levels by means of amplitude balance circuits, which must be adjusted correctly.

c. The gain of the delay and nondelay amplifiers must be equal in order to attain complete cancellation of fixed targets at the comparison point. The MTI automatic gain control circuit automatically adjusts the gain of the delay amplifier to equal that of the nondelay amplifier. If the circuit is not operating properly, fixed echoes will not be cancelled, and proper gated MTI operation will not be accomplished.

Section II. THEORY OF OPERATION

39. GENERAL

a. The 9-mc modulated signal applied to the nondelay amplifier channel (fig 31) is amplified by four stages of voltage amplifiers, V2301 to V2304, and one power amplifier, V2305. The power amplifier is transformer coupled to a detector (V2306) that is polarized so that the output video signal rides at a positive 5-volt level from the rectification of the carrier. Positive modulation of the carrier produces a positive video signal and negative modulation produces a negative video signal. The output of the detector, which is both positive and negative video at a positive dc level, is then sent to the comparison point where it is compared with the signal from the delay amplifier.

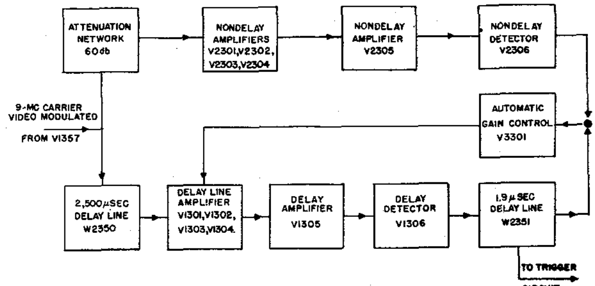

Figure 31. Block diagram of the nondelay and delay amplifiers.

b. The signal that has been delayed 2, 500 microseconds by the mercury delay tank is applied to the input of the delay amplifier (fig 31). The delay amplifier channel also has four stages of voltage amplifiers, V1301 to V1304, and one power amplifier, V1305. The detector output V1306 is polarized exactly opposite to that in the nondelay amplifier channel. In this case, the video signal rides at a negative 5-volt level and positive modulation produces negative video and negative modulation produces positive video. This signal is then sent to the comparison point to be compared with the signal from the nondelay channel.

c. At the comparison point, the signals from the fixed targets are cancelled and those from the moving targets are passed to the video amplifiers. A target echo, pulse number 1 (fig 32), appears simultaneously at the input of the delay network and nondelay amplifier and will be seen immediately at the comparison point because of its passage through the nondelay amplifier (A and B, at T_1 to T_2). It will again appear at the comparison point 2, 500 microseconds later because of its passage through the delay network and delay amplifier B at T_2. At that time, pulse number 2 has appeared at the input of the delay network and nondelay amplifier and appears at the comparison point at the same time as the delayed pulse number 1, A and B at T_2. Since the delay amplifiers invert the delayed video pulse, delayed pulse number 1 and nondelayed pulse number 2 will be of opposite polarity, C at T_2. If pulse number 1 and pulse number 2 are equal in amplitude, cancellation occurs, and the net video output at the comparison point is zero, as would be the case of a fixed target return. However, if pulse number 1 and pulse number 2 has different amplitudes, complete cancellation will not occur and a net video signal will remain, indicating a moving target. The next sequence of comparison would involve delayed pulse number 2 and nondelayed pulse number 3, and a continuous comparison of the returning video pulses by pairs is thus accomplished. In this manner, fixed targets or constant amplitude video pulses are completely eliminated at the comparison point. The moving target video remaining at the comparison point is applied to the video amplifier network and the indicator scopes.

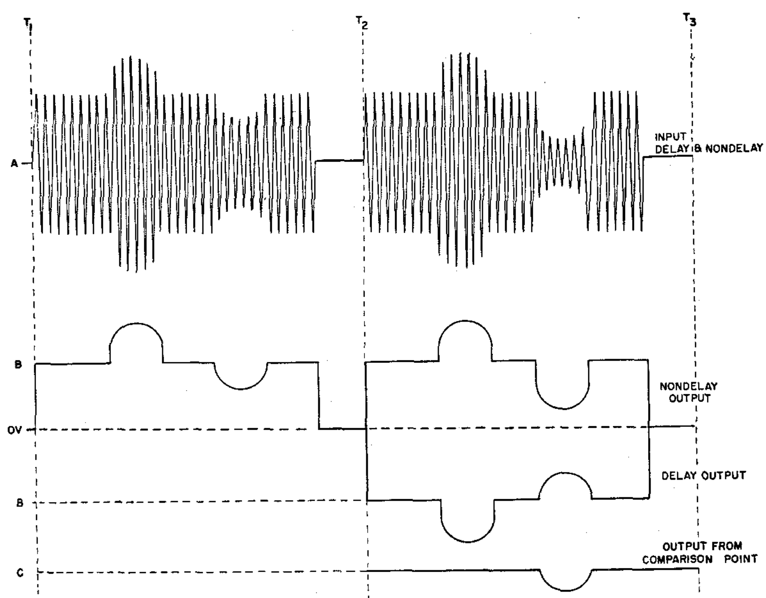

Figure 32. Signals at the comparison point.

d. To have complete cancellation of fixed targets at the comparison point, the gain of the nondelay and delay amplifiers must be equal. The gain of the nondelay amplifier is manually controlled by means of the NONDELAY AMPL OUTPUT control R2353. The gain of the delay amplifier could be controlled by a manual gain control, but, due to drift, the gain of the amplifiers would gradually change and would require frequent adjustment. The MTI automatic gain control has been incorporated into the MTI to correct this situation.

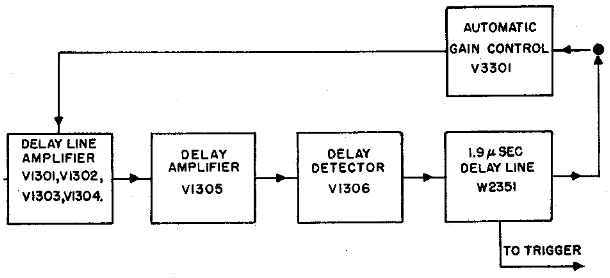

Figure 33. Block diagram of video balancer.

e. Figure 33 is a block diagram of the video balancer system (or MTI automatic gain control) showing how the circuit is used to control the gain of the delay amplifier. When the gain of the two amplifiers is the same, the output of the nondelay amplifier is video superimposed on a positive 5-volt level, while the output of the delay amplifier is video riding at a negative 5-volt level, and the resultant dc voltage is zero at the comparison point. If the gain of either the delay or nondelay amplifier changes, the net dc voltage at the comparison point changes from zero to some positive or negative voltage, depending upon which amplifier increases or decreases in gain.

f. If the delay amplifier increases in gain:

(1) The increases output of the delay amplifier causes an average negative voltage to appear at the comparison point.

(2) This negative voltage, being present at the input of the video balancer (V3301 A/B) causes the video balancer circuit to produce an increasing negative voltage.

(3) The negative voltage would be sent to the delay amplifier in the form of bias voltage, which decreases the gain of the delay amplifier until it is equal to that of the nondelay amplifier.

Section III. DETAILED CIRCUIT ANALYSIS

40. DELAY AMPLIFIER (fig 34.)

a. The delay amplifier amplifies and demodulates the 9-mc signals received from the quartz delay line. The video output is fed to the video balancer and amplifier for comparison with nondelayed video. The output video circuit is also connected to the MTI repetition rate trigger amplifier for generation of a 9-mc carrier gate and repetition rate triggers. The amplifier consists of five broadband stages, V1301-V1305, and a

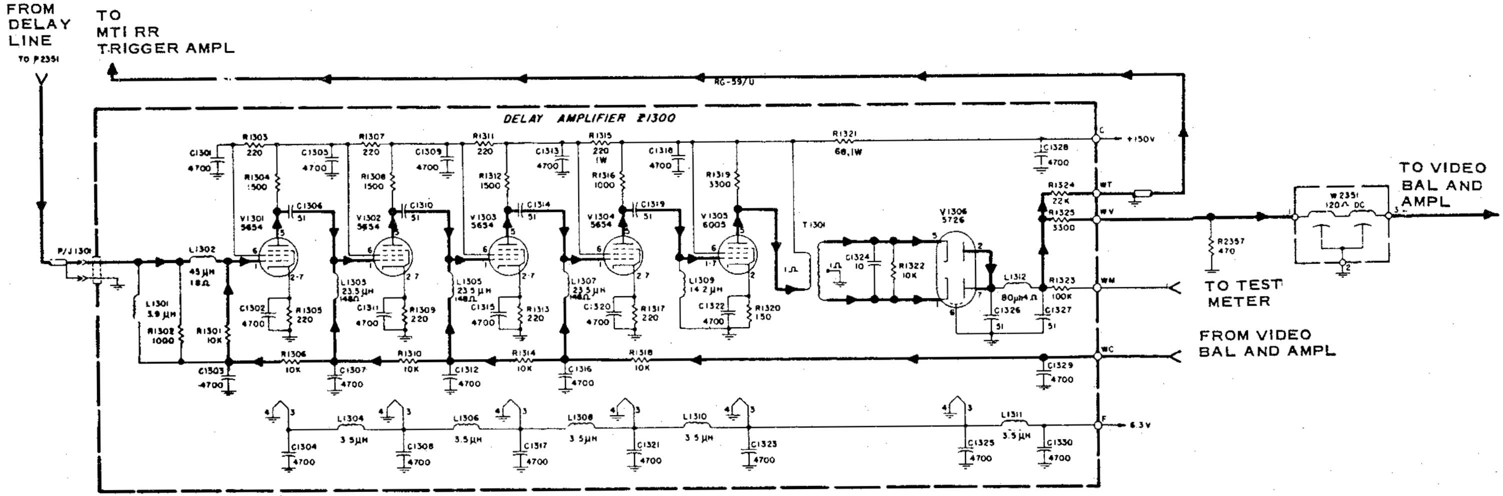

Figure 34. Delay amplifier.

full-wave second detector, V1306. The input circuit, consisting of L1301 and L1302, provides an impedance step up from the 90-ohm input cable to the grid of V1301. Appreciable gain in signal voltage to the grid of V1301 is realized from this arrangement.

b. All amplifier stages are fixed - tuned to 9 mc and broadbanded by loading resistors. The interstage tuned circuits consist of indicators L1303, L1305, L1307, and L1309, each tuned by the tube capacitances with which each inductor is associated. The gain of the amplifier is adjusted by bias control of V1301 - V1304. Bias is derived from the video balancer and amplifier, which automatically controls the output level of the delay amplifier to match the output level of the nondelay amplifier.

c. The full-wave detector V1306 is used to produce video with a ripple frequency of twice the signal frequency of the if amplifier. The output filter, consisting of C1326, L1312, and C1327 is designed for better discrimination between the rf and video signals. Also, the possibility of regenerative feedback around the amplifier is reduced, as the amplifier itself will discriminate against the ripple frequency.

d. Video output is fed to the grid of V3303, in the video balancer and amplifier, through R1325 and the delay network, W2351. The delay of W2351, approximately 1.9 microseconds, compensates for circuit delay accumulated in the nondelay signal circuits. The frequency versus impedance characteristic of W2351 is somewhat nonlinear, and therefore, would present an irregular load on the detector circuit. The shunt resistor tends to improve linearity, while the series resistor R1325 minimizes the irregular loading effect on the detector circuit.

e. The output video circuit to V1350 in the MTI repetition rate trigger amplifier is decoupled from the detector by R1324, which also provides some integration in conjunction with the capacitance of the RG-59/U interconnecting cable. To meter the output level, dc is taken from the detector and fed through isolating resistor R1323 to TEST SELECTOR switch S2353.

41. NONDELAY AMPLIFIER. (fig 35)

a. Attenuated signals (9 mc) from V1357 in the MTI repetition rate trigger amplifier are amplified and demodulated by the nondelay amplifier. The output video signals are fed to V3303 in the video balancer and amplifier, where they are compared with video from the delay amplifier.

b. With the exception of the gain control and the input and output circuits, the nondelay amplifier is identical to the delay amplifier described above. The amplifier tubes are V2301-V2305, and V2306 is the detector. The two amplifiers are made nearly identical so that the nondelayed and delayed circuit characteristics produce video which matches in waveform.

c. The 9-mc signal to the nondelay amplifier is attenuated approximately 60 db, 10 db of the attenuation being in the output circuit V1357 in the MTI repetition rate trigger amplifier and 50 db being in the input circuit of V2301. This amount of attenuation represents the maximum amount of loss possible in the quartz delay line, W2350, and also the attenuation of W2351, both of which are in the delayed signal circuit. Thus, the output levels of the two circuits are made approximately equal.

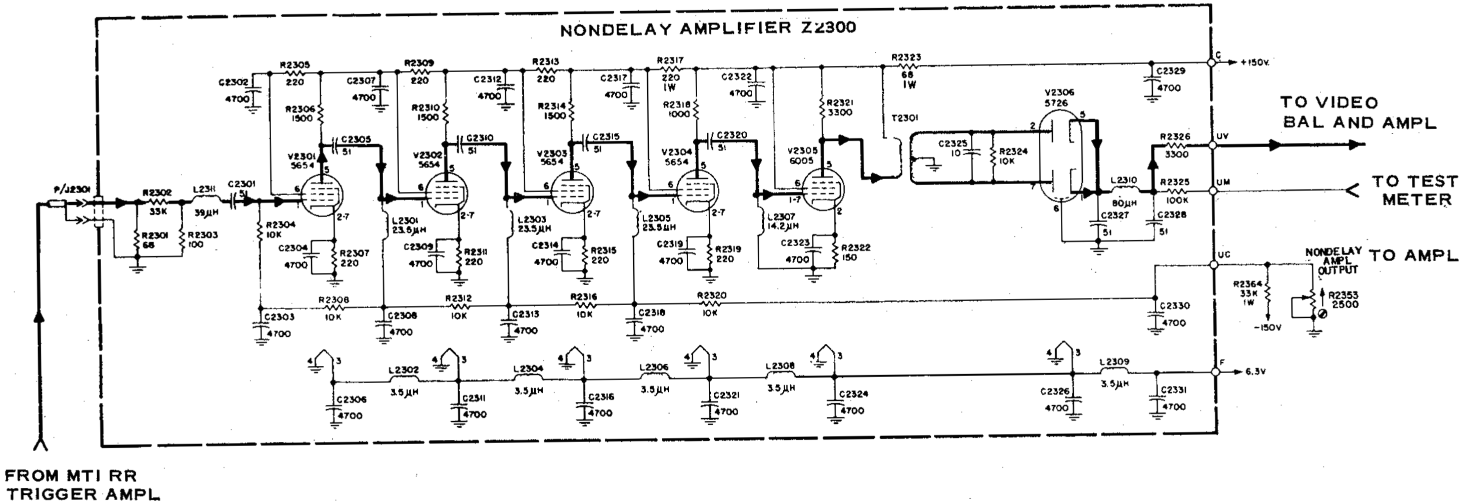

Figure 35. Nondelay amplifier.

d. The input inductance, L2311, tunes the input circuit to 9 mc. The series grid capacitor, C2301, serves only to isolate the dc bias voltage. The gain of the amplifier is adjusted by R2353, which controls the bias voltage to V2301—V2304. R2353 is in a voltage divider circuit between the -150 volt supply and ground.

e. The detector circuit V2306 is the same as that of the delay amplifier, except that the diode V2306 is poled to give positive video signals instead of negative. Therefore, when the outputs of the nondelay and delay amplifiers are combined (at the grid of V3303 in the video balancer and amplifier), the two signals cancel.

f. The positive video output signal, besides being fed to V3303 in the video balancer and amplifier, is also passed on to TEST SELECTOR switch, S2353, in the metering circuit. The metering circuit is isolated from the detector circuit by resistor R2325. The circuit is dc-coupled to the metering circuit, average dc values being used to set the amplifier output level.

Section IV. TROUBLESHOOTING

42. TEST METER M2350

The troubleshooting of the two channels that have been discussed can be aided by using TEST METER M2350. For proper operation, the two amplifier channels must be balanced; this is accomplished by using the meter and adjusting the necessary controls for a red line reading.

43. NONDELAY CHANNEL

To check for proper operation of the nondelay channel, position the OPERATION SELECTOR switch to gated MTI and the TEST SELECTOR to the NONDELAY AMPL OUTPUT position. If there is no reading at the meter and the adjusting of the NONDELAY AMPL OUTPUT control, R2353, does not vary the reading, the possible cause of the trouble is V2304, V2305, or V2306, including all associated circuitry. If a low meter reading is observed which can be varied slightly by R2353, the trouble should be in the circuitry of V2301, V2302, or V2303.

44. DELAY CHANNEL

In checking the correct operation of the delay amplifiers, set the TEST SELECTOR to AMPL BALANCE and the OPERATION SELECTOR to gated MTI. If no meter reading is possible after adjusting the AMPLITUDE BALANCE control, R2354, the cause may be defective components in the VIDEO BALANCER circuits, V3301A or V3302. Defective circuitry of V1304, V1305, or V1306 also gives no output from the delay channel. If a low reading is observed on the test meter that is slightly variable by adjusting R2354, the possible trouble may be in the circuits of V1301, V1302, or V1303. A high meter reading that cannot be controlled is usually due to a defective V3301B stage in the video balancer.

Section V. SUMMARY AND QUESTIONS

45. SUMMARY

a. The 9-mc modulated signal is applied to the nondelay and delay channels. The signal sent to the nondelay channel is passed without any delay through the amplifiers and detector to the comparison point. The signal sent to the delay channel is delayed 2, 500 microseconds by the quartz delay line and then passed through the delay amplifier and detector. This detector is polarized so that the output is inverted, in respect to the nondelay detector. By having a channel that delays and inverts the signal, the returns from one transmitted pulse can be compared with another.

b. When these signals arrive at the comparison point, the fixed targets cancel, since they are equal in amplitude and opposite in polarity. Moving targets, which change in amplitude and polarity, do not cancel and are passed to the video amplifiers for display on the indicators.

46. QUESTIONS

a. What is the total attenuation of R1385, R1386, R2301, R2302, and R2303 on the input signal to V2301?

b. What effect is noted at the nondelay detector output when the NONDELAY AMPL output control R2353 is increased in resistance?

c. What is the purpose of C2327, L2310, and C2328?

d. Draw the detected output from V2306 and label the time duration and voltage.

e. Draw the detected output from V1306 and label the time duration and voltage.

CHAPTER 6

VIDEO AMPLIFIER, VIDEO BALANCE, AND MTI GATE GENERATOR

Section I. INTRODUCTION

47. GENERAL

a. To obtain proper operation of the MTI system, bipolar video signals from the comparison point must be amplified, polarized, and limited before being sent to the indicator. Separate video amplifiers are provided for the MTI and normal video signals. The selection of either gated MTI or normal video is accomplished by the action of relays.

b. Since MTI video signals can be either positive or negative, a circuit is included that changes all MTI video signals to one polarity. To prevent amplitude variations of video signals on the scopes all signals are amplified and then limited to a maximum 30-volt level. Cathode followers are added to provide low impedance output circuits for the local and remote indicators.

c. The gain of the delay and nondelay amplifiers must be equal in order to attain complete cancellation of fixed targets at the comparison point. The video balancer circuit automatically adjusts the gain of the delay amplifier to equal that of the nondelay amplifier. If the circuit is not operating properly, fixed echoes will not be cancelled, and proper gated MTI operation will not be accomplished.

d. Within the signal-comparator unit are circuits that generate gating pulses for keying the normal and MTI video (in their correct sequence), thus providing gated MTI operation.

e. Two relays, in conjunction with OPERATION SELECTOR switch S2354, are used to select the desired mode of operation. Provision is made for controlling the MTI amplitude balance, MTI time balance,and MTI range gate from the indicator unit.

Section II. THEORY OF OPERATION

48. GENERAL

a. The comparison point is located at the input to the video amplifier, V3303 (fig 36). The gain of the amplifier is controlled by the MTI VIDEO GAIN control, R3306. Since V3303 is operating in class A, the output will be bipolar signals.

b. V3304 is a paraphase amplifier that produces two outputs that are equal in amplitude and opposite in polarity, as seen in figure 36. Two crystal rectifiers are connected to the outputs of the paraphase amplifier so that they will conduct only when their cathode is negative. With this type of connection, CR3301 will conduct on video pulse 1, and the CR3300 will conduct on pulse 2. Thus, two negative pulses appear at the input to V3305A. This stage then has changed the bipolar moving target video to unipolar video, which is necessary for proper presentation in the indicator system.

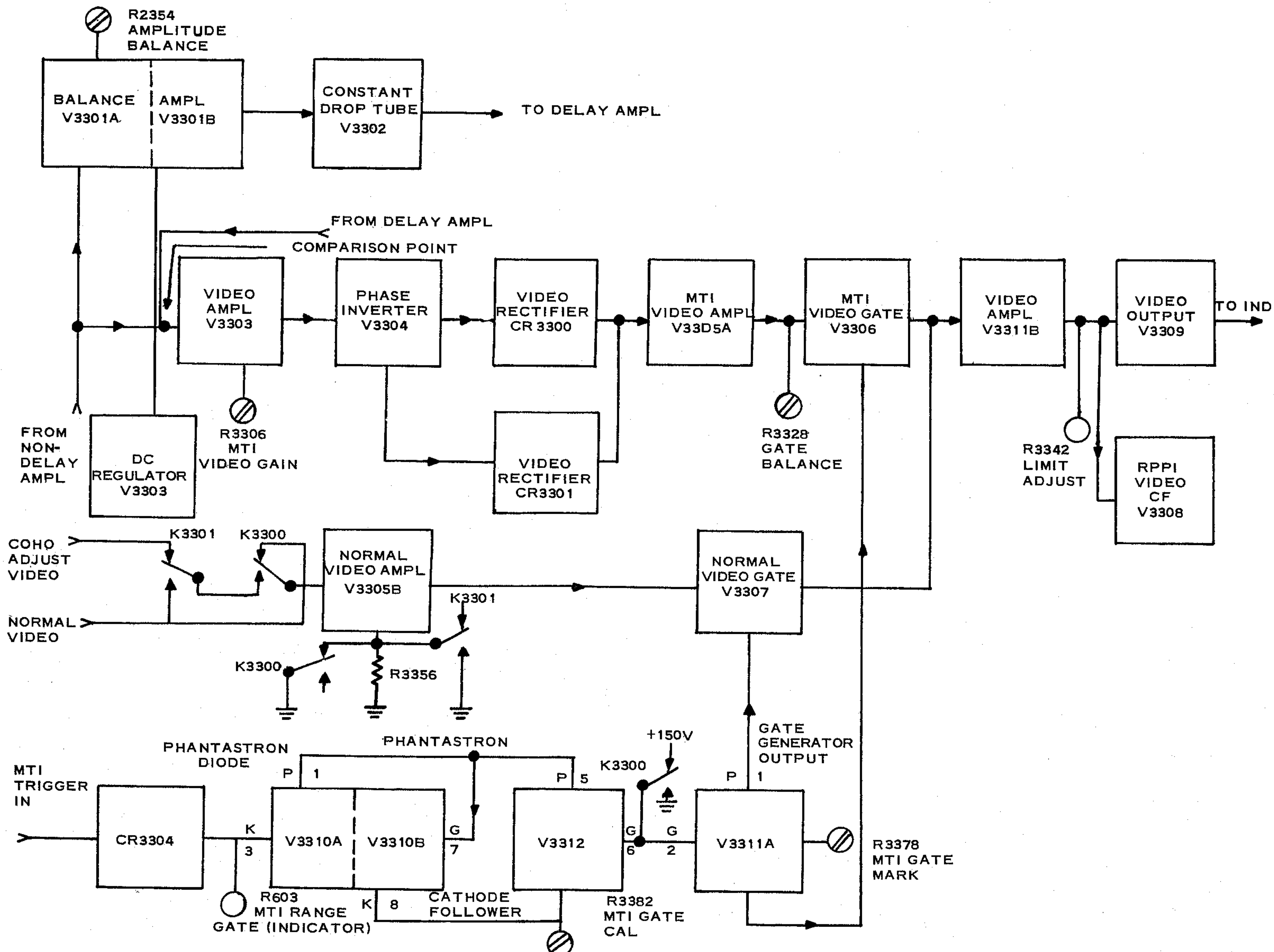

Figure 36. Block diagram of video balancer and amplifier, MTI gate generator.

c. The negative video signals are fed to the zero-biased MTI video amplifier V3305A where limiting is accomplished by operating the stage at a very low plate voltage. Positive signals are passed to the grid circuit of V3306, the MTI gate. Gate balance control R3328 permits adjusting the bias so that the MTI dc level of V3306 can be made equal to that of the normal video level of V3307. The circuitry and action of V3305B (normal video amplifier) and V3307 (normal gate) are identical with V3305A and V3306 respectively, except for the absence of a bias adjustment and the inclusion of the relay circuits of K3300 and K3301.

d. The outputs of V3305A and V3305B are fed to the control grids of V3306 and V3307 respectively.

(1) In normal operation, V3306 is held at cutoff by the MTI gate generator. This permits V3307 to pass signals on to video amplifier V3311B.

(2) In gated MTI operation, V3307 is cut off and V3306 is conducting until the switch over from MTI to NORMAL occurs. After the transition, V3306 is cut off and V3307 conducts. Since these 2 stages have a common plate load, either MTI or NORMAL video is coupled on to video amplifier V3311B.

e. The parallel-connected plates of V3306 and V3307 pass the signal on to V3311B, where both normal and MTI signals are amplified. The video signals from V3311B are fed to cathode followers V3308 and V3309, the grid circuits of which are parallel connected although the cathode circuits provide separate outputs.

f. The MTI gate pulses are generated in the phantastron circuit of V3312. When a negative trigger pulse is applied to the phantastron from the repetition rate generator (through diode V3310A and cathode follower V3310B), a switching action occurs, resulting in the generation of a pulse that then enables the MTI circuits and disables the normal video circuits. The duration of this pulse determines the point (in time and consequently in range) at which the system switches from MTI back to normal operation.

g. The output positive square wave is directly coupled to the grid of phase splitter V3311A. The outputs of V3311A are identical in amplitude and waveform but of opposite polarity. These outputs alternately gate V3306 and V3307 conduction. This action provides gated MTI.

h. To have complete cancellation of fixed targets at the comparison point, the gain of the nondelay and delay amplifiers must be equal. The gain of the nondelay amplifier is manually controlled by means of the NONDELAY AMPL OUTPUT control, R2353. The gain of the delay amplifier could be controlled by a manual gain control, but, due to drift, the gain of the amplifiers would gradually change and would require frequent adjustment. The video balancer, which is an automatic gain control, has been incorporated into the MTI to correct this situation. Figure 36 shows how the video balancer circuit is used to control the gain of the delay amplifier. The bias for controlling the gain of the delay amplifier is developed by regulator tubes V3300 and V3302, and dc amplifier V3301. When the gain of the two amplifiers is the same, the output of the nondelay amplifier is video-superimposed on a positive 5-volt level, while the output of the delay amplifier is video-riding at a negative 5-volt level, and the resultant dc voltage is zero at the comparison point. If the gain of either the delay

or nondelay amplifier changes, the net dc voltage at the comparison point changes from zero to some positive or negative voltage, depending upon which amplifier increases or decreases in gain.

Section III. DETAILED CIRCUIT ANALYSIS

49. VIDEO BALANCER AND AMPLIFIER (Fig 37)

a. In this section of the signal comparator, video signals from the delay and nondelay amplifiers are combined; and the difference signal voltage, if any, is amplified, limited, and fed to the indicator for MTI display. As MTI video input signals can be either positive or negative, a circuit is included which brings MTI video signals to one polarity. Separate video amplifiers are used for MTI and normal radar input signals, the amplifiers being arranged for video limiting. Video output signals for remote indicator use are made available on a separate low-impedance circuit. The selection of either MTI or normal radar signals is accomplished by relay operation. Bias voltage for controlling the gain of the delay amplifier is also developed in this section of the signal comparator. It is by this means that the video levels of the delay and nondelay amplifiers are balanced.

b. The circuits of this section consist of MTI video-combining amplifier V3303, video polarizer V3304 (also includes two crystal rectifiers CR3300 and CR3301), MTI video limiter-amplifier V3305A, normal video limiter-amplifier V3305B, MTI gate V3306, normal video gate V3307, video amplifier V3311B, output cathode follower V3308 for indicator, and output cathode follower V3309 for repeater PPI. The bias for controlling the gain of the delay amplifier is developed by regulator tubes V3300 and V3302, and dc amplifier V3301.

c. The video signals, together with second-detector dc components, are fed to the grid of V3303 from the delay and nondelay amplifiers. The series resistors, R3302 and R3303, provide isolation between the two signal input circuits. As the dc components are of opposite polarity, they cancel at the grid of V3303 when the second-detector levels of the two circuits are in balance. If the dc levels are not equal, the difference voltage is developed across C3311 in the grid return of V3303. This voltage is used to develop delay amplifier bias (explained below) and thus balance the dc levels of the two input signals. The two video signals are also of opposite polarity, and if they are of equal amplitude (as received from fixed targets), they cancel and no signal is applied to the grid of V3303. However, signals, as received from moving targets, generally have different video amplitudes, and therefore, the difference voltage is applied to the grid of V3303. This video difference voltage has negligible effect on the gain-balancing circuit because the integrated signal voltage developed across C3311 is negligible. As the resultant video signal can be either positive or negative, V3303 is operated with normal bias (cathode) for class A operation. The gain of V3303 is controled by MTI GAIN control R3306, which is unbypassed and therefore controls the amount of cathode circuit degeneration.

d. The signal amplified by V3303 is fed to V3304, which has equal load resistance (R3315 and R3318) in both the plate and cathode circuits. Video signals of equal amplitude but of opposite polarity are thus developed. Output signals from the plate circuit of V3304 are fed to crystal diode CR3300, and those from the cathode circuit are fed to CR3301, also a

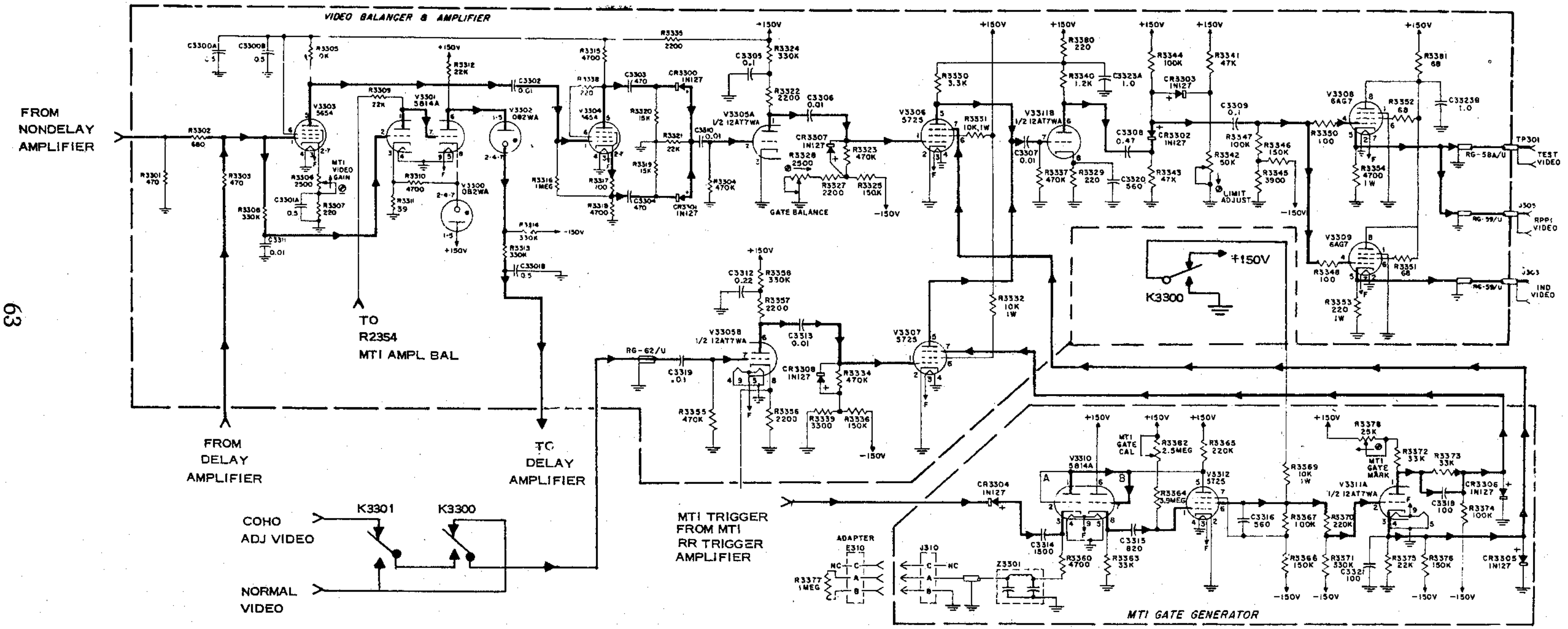

Figure 37. Video balancer and amplifier, MTI gate generator.

crystal diode. Both crystals are connected so as to develop negative video signals across the common load resistor, R3321. Therefore, regardless of the polarity of video input signals, only negative signals result, the diode which conducts being the one receiving negative video signals. The negative video signals are fed to the zero-biased MTI video amplifier, V3305A, where limiting is accomplished by operating the stage at a very low plate voltage. Positive signals are passed through C3306 to the grid circuit of V3306, the MTI gate. The voltage divider network consisting of R3325, R3327, and R3328 establishes a bias of approximately −3 volts on V3306. CR3307 is a dc restorer which conducts when the signal tries to go below −3 volts, and thus sets the dc level. GATE BALANCE control R3328 permits adjusting the bias so that the MTI dc level of V3306 can be made equal to that of the normal video level of V3307. The circuitry and action of V3305B (normal video amplifier) and V3307 (normal gate) is identical with V3305A and V3306 respectively, except for the absence of a bias adjustment, and the inclusion of the relay circuits of K3300 and K3301.

e. Relays K3300 and K3301 operate to close the cathode and grid circuits of V3305B. When OPERATION SELECTOR S2354 is in COHO ADJUST position, K3300 operates to include the cathode degeneration resistor, R3356, and thus decrease the gain of V3305B. During NORMAL and GATED MTI operation, K3300 and K3301 feed normal video from CR304 of the 60-mc if amplifier to the grid of V3305B. During COHO ADJUST, 60-mc phase-locked signals are fed to the grid of V3305B through alternate contacts of K3300 and K3301.

f. The outputs of V3305A and V3305B are fed to the control grids of V3306 and V3307 respectively. Both signals are positive, and V3306 and V3307 are both operated with approximately −3 volts on their grids; however, actual conduction is a function of the gating pulse, fed to the suppressor grid of each stage, from the MTI gate generator. While one stage is conducting as a result of positive signal (gate-pulse) to its suppressor grid, the other stage is cut off due to a negative signal to its respective grid. The conducting stage is then cut off and the original cut off stage conducts. Thus, gated MTI is produced by electronic switching of normal radar or MTI signals to the indicator. The parallel-connected plates of V3306 and V3307 then pass the signal on to V3311B, where both normal and MTI signals are amplified. Limiting is accomplished by operating the stage into the diode-limiting circuit consisting of CR3302, CR3303, R3341, R3342, R3343, and R3344. With no signal applied, CR3302 is conducting continuously and the voltage divider R3344/R3343 establishes the voltage across R3343 at approximately 50 volts. LIMITER control R3342 is adjusted for a voltage of approximately 54 volts at the junction of R3342 and CR3303. When the positive video signals are passed through C3308 and applied across R3343, CR3302 ceases to conduct, and the stray capacity existing between ground and the junction of the two diodes immediately starts charging toward 150 volts. The capacity is very small and the rise time is therefore very small. When the plate side of CR3303 tries to rise above the cathode side, the diode conducts and limits the signal level to the voltage set by R3342. The limited video signals from V3311B are fed to cathode followers V3308 and V3309, whose grid circuits are parallel-connected, but whose cathode circuits provide separate outputs. V3309 feeds video signals to the indicator via J303. V3308 provides video on a 70-ohm circuit for remote indicator use, a 150-ohm 1-watt resistor being required at the indicator end of the circuit. The output of V3308 also is available at test point TP301 for tuning purposes. It is also necessary to use a 150-ohm resistor across the meter or other test equipment when using TP301.

g. In developing bias for automatic gain control of the delay amplifier, the difference in the second-detector dc voltages of the delay and nondelay amplifiers is used for reference. This differential voltage is amplified, and used for bias gain control of the delay amplifier. This requires a dc amplifier which has no dc in its output circuit when there is no dc applied to the input circuit. The requirement is met by the use of the two-stage dc amplifier, V3301A/B, and the two 108-volt regulator tubes V3300 and V3302. Reference voltage is derived across C3311 as described above. When AMPL BALANCE control R2354 is in its midposition, there is approximately +40 volts at the plate of V3301A and also approximately +40 volts at the grid of V3301B. V3300 maintains the cathode of V3301B at +42 volts, with a resultant V3301B bias of approximately -4 volts. Regulator V3300, besides holding the cathode bias of V3301B at a fixed value, maintains the cathode bias of V3301A nearly constant. The static condition of the amplifier is thus stabilized. When the dc output level (measured at the junction of C3301B and R3313) is zero, the voltage at the plate of V3301B is 108 volts. As V3302 is connected between the plate of V3301B and the output circuit, and as the drop across V3302 is maintained at 108 volts, the output voltage will be 108 volts subtracted algebraically from the plate voltage of V3301B, or zero volts. It is possible to have either negative or positive output voltage because the current circuit of V3302 is returned to -150 volts through R3314. R3314 is made several times greater than the V3301B plate-load resistor R3312, so the voltage developed across R3312 is mainly controled by the plate current of V3301B. With zero volts output, the gain of the delay amplifier is high. Therefore, when the input video levels are balanced by AMPL BALANCE control R2354, the output voltage is slightly negative to reduce the gain of the delay amplifier. Automatic balancing bias voltage then varies above and below this negative value. The time constant of the dc amplifier input circuit (R3308 and C3311) and output circuit (R3313 and C3301B) is approximately one-sixth of a second, thus enabling the balancing circuit to carry over gating periods of the timing circuit and also to follow only averaged trends.

50. MTI GATE GENERATOR (Fig 36)

a. In this section of the signal comparator are generated the gating pulses that key in the normal and MTI video, in their correct sequence, for gated-MTI operation.

b. The gate pulses are generated in the phantastron circuit of V3312. A phantastron is a circuit for producing a controllable delay time, and functions in much the same way as a conventional multivibrator using two triodes. One section of the multivibrator is comprised of the cathode, control grid and screen grid (plate circuit); the other section being the cathode, suppressor grid (control grid) and plate. The action of the multivibrator is to produce square waves at the screen grid of the phantastron, which are then used for gating. The section having the screen grid as the plate is the normally on tube, and the other section the normally off tube. During this normal condition, the output of the gate generator is enabling the normal video circuits in the video amplifier and disabling the MTI circuits. When a negative trigger pulse is applied to the phantastron from the repetition rate generator (through diode V3310A and cathode follower V3310B) a switching action occurs, the result of which is the generation of a pulse which enables the MTI circuits and disables the normal video circuits. The duration of this pulse determines the point (in time and, consequently, in range) at which the system switches from MTI to normal operation. The pulse duration is a function of the voltage to which C3315 charges. Diode V3310A and MTI RANGE GATE control R603, provide

a means of controlling the pulse duration, by controling the voltage to which C3315 can charge. Adjusting R603, which is located on the front panel of the indicator, changes the voltage applied to the cathode of V3310A. Since the plate of this diode is connected to the plate of the phantastron, when the plate voltage of the phantastron reaches the value of the cathode voltage, the diode conducts and clamps the voltage to which C3315 can charge. C3315 has a very constant discharge rate, so that the change in pulse duration is almost a perfectly linear function of the change in voltage at the tap of R603. This control is calibrated directly in miles.

c. The MTI GATE CAL control R3382, also affects the charging time of C3315 and provides the means by which R603 can be calibrated. MTI RANGE GATE control R603 is set to 160 and R3382 is adjusted so that the MTI-gate marker coincides with the 160-mile marker on the A-scope. MTI GATE MARK control R3378 adjusts the intensity of the MTI-gate marker. The marker is produced by a small overlap of the trailing edges of the two gate pulses. R3378 varies the time constant of the plate circuit of V3311A and consequently changes the wave-shape of the gate pulse by varying the slope of the trailing edge of the pulse. This in turn varies the amount of overlap of the plate and cathode pulses and thereby varies the intensity of the marker. Cathode follower V3310B reduces the time necessary to charge C3315. In the absence of the cathode follower C3315 would have to charge through the plate load of V3312, and a long period would be required after the pulse before the circuit was ready for the next trigger. The output of the phantastron is taken off the screen grid, the waveform being a positive square wave. This signal is directly coupled to the grid of phase splitter V3311A. The outputs of V3311A are identical in amplitude and waveform but of opposite polarity. The cathode of V3311A is connected to the suppressor grid of the MTI gating stage V3306 while the plate of V3311A is connected to the suppressor grid of V3307, the normal video gating amplifier. Thus, the positive going pulse keys in the MTI stage at the beginning of the receiving period while the normal stage is cut off. At a point determined by the setting of MTI RANGE GATE control R603, the MTI stage is then cut off and the normal stage conducts. At the end of the receiving period (2, 500 microseconds) the trigger pulse triggers the phantastron and the cycle is repeated with the MTI circuits again being enabled. Diodes CR3305 and CR3306 clamp the gating pulses to ground. CR3304 prevents any positive signal from triggering the phantastron. Z3301 is a line-noise filter, which prevents any transient signals from affecting the operation of the MTI circuitry. Relay K3300 operates to remove screen voltage from the phantastron during normal operation thereby disabling the gate generator. In the absence of gate pulses, V3307 conducts continuously while V3306 remains cutoff.

Section IV. TROUBLESHOOTING

51. VIDEO AMPLIFIERS

a. Troubles that may occur in the video amplifiers may be grouped into three general classifications. There are troubles that cause the loss of:

(1) MTI video only.

(2) NORMAL video only.

(3) Both MTI and NORMAL video.

b. If video is present in NORMAL operation, but not in MTI, the trouble could possibly be in the MTI video amplifier stages, V3303, V3304, V3305A, and V3306. Remember that loss of MTI video could be caused by failure of some part of the MTI circuitry preceding the video amplifiers; this can usually be located by the TEST METER readings in its various test positions. Failure of normal video amplifier and gate, V3305B, and V3307 would cause loss of normal video, but not of MTI video. If V3311B fails to operate, both MTI and NORMAL video would be eliminated.

52. THE VIDEO BALANCER CIRCUIT

a. A trouble in the video balancer circuit will probably show up in the MTI tuning procedure when adjusting the AMPLITUDE BALANCE control for a red-line reading on TEST METER M2350. It is necessary for proper operation of the video balancer that the +150 volts be adjusted to balance the -150 volts from the power supply. If there is trouble in adjusting the AMPLITUDE BALANCE control (R2354) for a red-line reading, this voltage should be checked before any other troubleshooting steps are taken.

b. If the test meter reads full scale when monitoring the AMPLITUDE BALANCE output, the possible trouble could be the nonconduction of V3301B. Before checking the stage, the AMPLITUDE BALANCE control (R2354) should be varied in an attempt to correct the high meter reading. If the test meter reading is zero, the possible troubles could be that:

(1) V3301A is not conducting.

(2) V3300 is not conducting.

(3) V3302 is not conducting.

c. Remember that the inability to red line the test meter in the AMPLITUDE BALANCE position does not necessarily mean that the trouble is in the video balancer circuit. The trouble could be in either the delay or the nondelay amplifier channels, Therefore, if the trouble cannot be located in the video balancer, the delay and nondelay amplifiers should be checked.

53. MTI GATE GENERATOR

a. In the absence of gate pulses, V3307 conducts continuously while V3306 remains cutoff. The negative trigger pulse from the repetition rate generator causes the generation of a pulse which enables the MTI circuits. Relay K3300 operates to remove screen voltage from the phantastron during normal operation thereby disabling the gate generator.

b. The failure of the MTI gate generator to generate gate pulses can be caused by no MTI trigger pulse input to the circuit, bad CR3304, faulty stages V3310A, V3310B, V3312, V3311A, or by relay K3300. V3310A and R603 (indicator) control the gate pulse duration.

54. VIDEO AMPLIFIER

a. The purpose of the MTI video amplifiers is to amplify, convert to unipolar video, and limit moving target video so that it may be presented in the correct manner on the screens. Bipolar video from the comparison point is amplified by the class A amplifier V3303 with its gain controlled by the MTI video gain control R3306. The output of V3303 is bipolar video and is applied to V3304. V3304, in conjunction with CR3300 and CR3301, converts all bipolar video to unipolar video in order to obtain proper presentation on the screens. Negative video signals are fed to the MTI video amplifier V3305A which amplifies, inverts, and limits all MTI video signals. Positive signals are passed to the grid circuit of V3306, the MTI gate. The circuitry and action of V3305B (normal video amplifier) and V3307 (normal gate) are identical with V3305A and V3306, except for the absence of a bias adjustment and the inclusion of the relay circuits of K3300 and K3301. V3306 and V3307 pass the signal on to V3311B, where both normal and MTI signals are amplified. The signals from V3311B are fed to V3308 and V3309, and from there to the remote indicator and the indicator unit.

b. When changing from NORMAL to MTI operation, the automatic switching of all circuits is accomplished by the OPERATION SELECTOR switch S2354 in conjunction with relays K3300 and K3301. Also, certain controls on the signal comparator are remoted to the indicator unit to facilitate final MTI adjustments and ease in operation.

55. VIDEO BALANCER

The purpose of the video balancer circuit (V3300, V3301, and V3303) is to provide an automatic bias control for the first four stages of the delay amplifiers. The biasing actions enable the gain of the delay and nondelay amplifiers to be kept equal. The input to the video balancer is taken from the comparison point and represents the algebraic sum of the output voltages of the two amplifier channels.

56. MTI GATE GENERATOR

Within the signal-comparator unit are circuits that generate gating pulses for keying the normal and MTI video (in their correct sequence), thus providing gated MTI operation.

57. QUESTIONS

a. What is the polarity of the MTI video signals at the output of the comparison point, grid of V3303?

b. What is the effect on the grass level at the A-scope, when the MTI VIDEO GAIN control, R3306, is increased in resistance?

c. What is the overall purpose of V3304, CR3300, and CR3301?

d. What is the polarity of the video signals at the grid of V3305A?

e. What is the polarity of the video signals at J303?

f. If R3321 should become shorted, what would be the effect on gated MTI operation? On NORMAL operation?

g. If CR3300 were to short, what would be the effect on NORMAL operation?

h. What would be the effect on the radar operation if K3300 fails to energize?

i. What is the purpose of cathode follower V3308?

j. The RECEIVER GAIN control, R308, will vary the gain of the if amplifiers when the OPERATION SELECTOR switch, S2354, is set to the ______________________________ position and the SYSTEM SELECTOR switch S601 is set to the ______________________________ position.

k. Which channel of the signal comparator is controlled in gain by the video balancer circuit?

l. What is the adjustment control for manually varying the gain of the delay amplifier?

CHAPTER 7

MTI SWITCHING CONTROLS TROUBLESHOOTING AND ALINEMENT OF THE MTI SYSTEM

Section I. MTI SWITCHING CONTROLS

58. GENERAL

a. The OPERATION SELECTOR switch (S2354) is a 6-gang, 4-position rotary switch, located on the right front of the signal comparator. The purpose of this switch, when used in conjunction with K3300 and K3301, is to select the proper mode of operation. Figure 37 shows the complete action of the OPERATION SELECTOR switch in connection with K3300 and K3301. The four positions of the switch are position 1, NORMAL; position 2, COHO ADJUST; position 3, GATED MTI; and position 4, REMOTE (fig 38).

b. The COHO LEVEL potentiometer R2351 adjusts the voltage to the V353 screen (acting as the grounded plate of the oscillator), and hence sets the output level of the oscillator. One set of K3301 contacts opens the V353 screen supply to disable the oscillator for NORMAL radar operation.

c. Relays K3300 and K3301 operate to close the cathode and grid circuits of V3305B. When OPERATION SELECTOR switch S2354 is in COHO ADJUST position, K3300 operates to include the cathode degeneration resistor, R3356, and thus decrease the gain of V3305B. During NORMAL and GATED MTI operation, K3300 and K3301 feed normal video from CR304 of the 60-MC if amplifier to the grid of V3305B. During COHO ADJUST, 60-mc phase-locked signals are fed to the grid of V3305B through alternate contacts of K3300 and K3301.

d. Relay K3300 operates to remove screen voltage from the phantastron (V3312), in the MTI gate generator, during NORMAL operation thereby disabling the gate generator.

e. Located on the front panel of the indicator unit are the MTI AMPLITUDE BALANCE, MTI TIME BALANCE, and RECEIVER GAIN controls. These controls are switched into their respective circuits through the contacts of relay K3301 when the OPERATION SELECTOR on the signal comparator is set to the REMOTE position. (At the same time, the same controls in the comparator are disconnected.) Also on the front panel is the MTI RANGE GATE control R603.

59. OPERATION SELECTOR SWITCH S2354

a. In the NORMAL position, the OPERATION SELECTOR switch does the following:

(1) In the A-section, the switch energizes K3300, which deactivates the MTI gate generator by removing screen voltage from V3312.

(2) In the B-section, the switch energizes K3301, which activates the NORMAL video amplifier, V3305B, by grounding its cathode. It allows the gain of the first and third

if amplifiers to be adjusted by IF AMPL LEVEL control, R2350. The coho oscillator is made inoperative by removing its B+ voltage, 150 volts.

(3) In the C-section, the switch removes ground from the output of V307, allowing the output of the 60-mc if amplifier to be read on M2350.

(4) In the D-section, the switch connects the IF AMPL LEVEL control, R2350, into the circuit, in order to adjust the gain of the if amplifier.

(5) In the E-section, the switch connects the MTI TIME BALANCE control, R2356, into the circuit, in order to adjust the bias on V1351.

(6) In the F-section, the switch connects the MTI AMPLITUDE BALANCE control, R2354, into the circuit, in order to adjust the output level of the video balancer.

b. In the COHO ADJ position, the OPERATION SELECTOR switch S2354 does the following:

(1) In the A-section, the switch energizes K3300, which disables the MTI gate generator.

(2) In the B-section, the switch deenergizes K3301, which removes ground from the cathode of V3305B, putting R3356 in its cathode circuit and decreasing its gain; it also activates the coherent oscillator V353 by supplying B+, 150 volts to it.

(3) In the C-section, the switch shorts the output of metering tube V307 to ground.

(4) In the D-, E-, and F-sections, the switch performs the same function as in the D-, E-, and F-sections when the switch is in NORMAL.

c. In the GATED MTI position, the OPERATION SELECTOR switch S2354 does the following:

(1) In the A-section, the switch deenergizes K3300, which activates the MTI gate generator by supplying screen voltage to V3312.

(2) In the B- and C-sections, the switch performs the same function as in the B- and C-sections when the switch is in COHO ADJUST.

(3) In the D-, E-, and F-sections, the switch performs the same function as in the D-, E-, and F-sections when the switch is set to NORMAL.

d. When the OPERATION SELECTOR switch S2354 is in REMOTE position the operation of the signal comparator circuits can be accomplished at the indicator unit. The SYSTEM SELECTOR switch, S601, selects the mode of operation by controlling the operation of relays K3300 and K3301. With the SYSTEM SELECTOR switch in NORMAL position, the gain of the if amplifier is controlled by RECEIVER GAIN control, R608, on the indicator. Since it is necessary to observe the A-scope when adjusting the MTI AMPLITUDE BALANCE and MTI TIME BALANCE controls, the controls are on the indicator.

60. TROUBLESHOOTING

a. Most of the troubles in the switching circuits are associated with the two relays, K3300 and K3301. These troubles, caused by either dirty relay contacts or broken wires, usually show up as faulty operation in 1 or more of the 3 modes of operation.

b. One method that is sometimes helpful in locating the defective relay is to tap lightly on the chassis, directly above the relay, while observing either the test meter or the A-scope for an indication. To locate the defective contact, it is usually necessary to observe the relay action while changing the position of the OPERATION SELECTOR switch S2354. Arcing will usually be present at a dirty relay contact. The proper procedure for cleaning relay contacts can be found in TM 11-1167, page 6-12.

Section II. TROUBLESHOOTING THE MTI SYSTEM

61. SIGNAL COMPARATOR

a. As the signal comparator consists of eight separate sections (five being subassemblies), each with a definite function, it should be possible to segregate a fault without too much difficulty. As a reference the eight sections are listed as follows:

60-mc if amplifier (subassembly)
Coho (coherent oscillator) (subassembly)
MTI repetition rate trigger amplifier (main chassis)
Delay amplifier (subassembly)
Nondelay amplifier (subassembly)
Delay network (subassembly)
Balancer and amplifier (main chassis)
Gate generator (main chassis)

b. When normal radar reception is in use, only the 60-mc if amplifier and part of the balancer and amplifier circuits are involved. When gated MTI is in use, these sections plus the remaining sections are involved.

c. It follows that if trouble is encountered on both MTI and normal radar operation, there is a good likelihood of the trouble being in the 60-mc amplifier, in the balancer and amplifier, or in the power supply for these sections. If the trouble is present only on MTI, the remaining sections then should be investigated.

d. The test meter of the unit provides a check of the output levels of the 60-mc if amplifier, coho, repetition rate trigger amplifier (DELAY LINE INPUT position), nondelay amplifier, and delay amplifier. Therefore, measurements taken of these circuits, by the use of the test meter and TEST SELECTOR switch, provide an indication of possible fault in a particular section.

e. The delay network can be checked for maximum attenuation by substituting the test attenuator (mounted on fuse clips above the unit chassis) for the network. The test procedure is given under paragraph 35b. In taking the measurements mentioned in the preceding

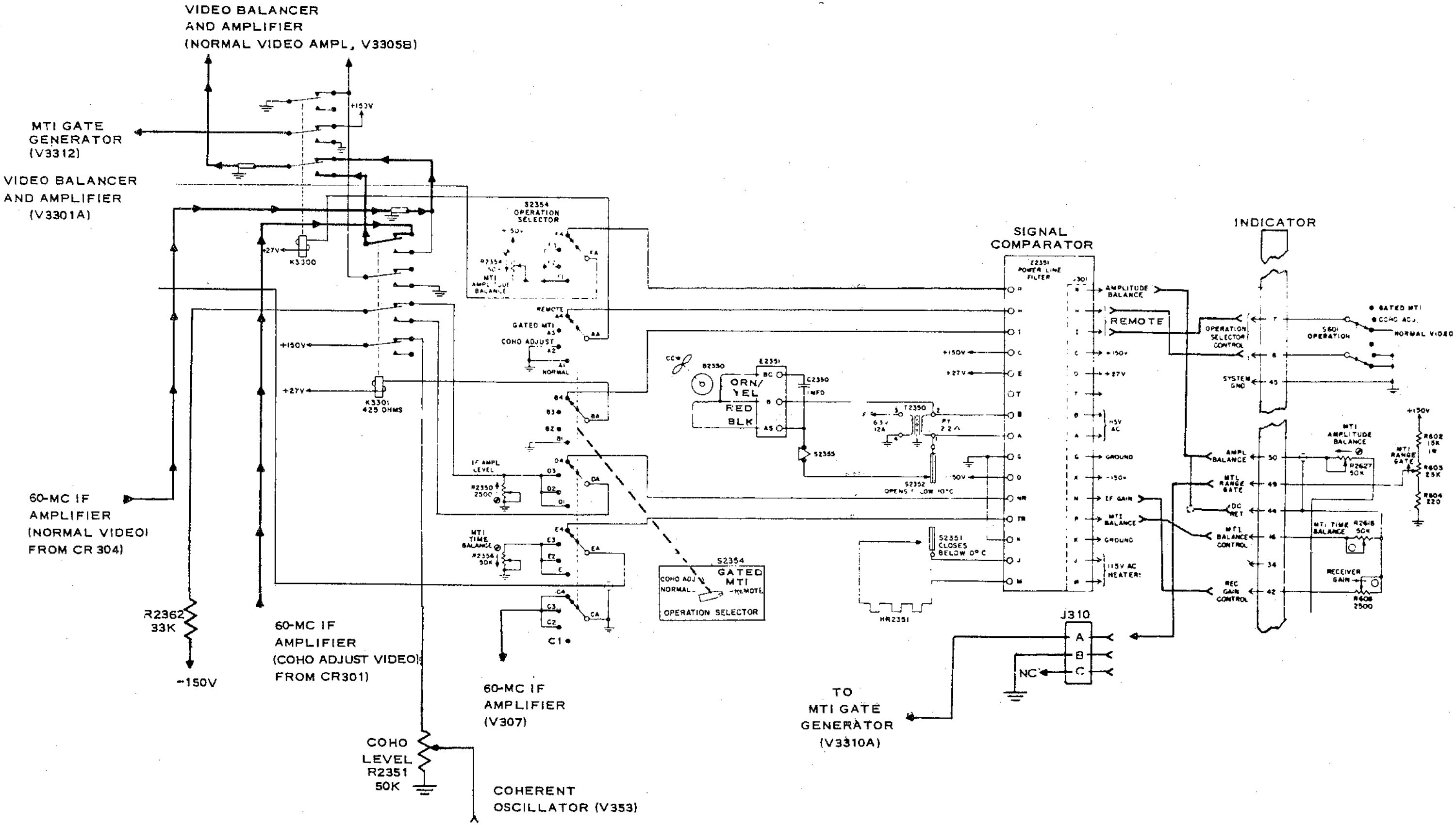

Figure 38. MTI switching controls.

if amplifiers to be adjusted by IF AMPL LEVEL control, R2350. The coho oscillator is made inoperative by removing its B+ voltage, 150 volts.

(3) In the C-section, the switch removes ground from the output of V307, allowing the output of the 60-mc if amplifier to be read on M2350.

(4) In the D-section, the switch connects the IF AMPL LEVEL control, R2350, into the circuit, in order to adjust the gain of the if amplifier.

(5) In the E-section, the switch connects the MTI TIME BALANCE control, R2356, into the circuit, in order to adjust the bias on V1351.

(6) In the F-section, the switch connects the MTI AMPLITUDE BALANCE control, R2354, into the circuit, in order to adjust the output level of the video balancer.

b. In the COHO ADJ position, the OPERATION SELECTOR switch S2354 does the following:

(1) In the A-section, the switch energizes K3300, which disables the MTI gate generator.

(2) In the B-section, the switch deenergizes K3301, which removes ground from the cathode of V3305B, putting R3356 in its cathode circuit and decreasing its gain; it also activates the coherent oscillator V353 by supplying B+, 150 volts to it.

(3) In the C-section, the switch shorts the output of metering tube V307 to ground.

(4) In the D-, E-, and F-sections, the switch performs the same function as in the D-, E-, and F-sections when the switch is in NORMAL.

c. In the GATED MTI position, the OPERATION SELECTOR switch S2354 does the following:

(1) In the A-section, the switch deenergizes K3300, which activates the MTI gate generator by supplying screen voltage to V3312.

(2) In the B- and C-sections, the switch performs the same function as in the B- and C-sections when the switch is in COHO ADJUST.

(3) In the D-, E-, and F-sections, the switch performs the same function as in the D-, E-, and F-sections when the switch is set to NORMAL.

d. When the OPERATION SELECTOR switch S2354 is in REMOTE position the operation of the signal comparator circuits can be accomplished at the indicator unit. The SYSTEM SELECTOR switch, S601, selects the mode of operation by controlling the operation of relays K3300 and K3301. With the SYSTEM SELECTOR switch in NORMAL position, the gain of the if amplifier is controlled by RECEIVER GAIN control, R608, on the indicator. Since it is necessary to observe the A-scope when adjusting the MTI AMPLITUDE BALANCE and MTI TIME BALANCE controls, the controls are on the indicator.

60. TROUBLESHOOTING

a. Most of the troubles in the switching circuits are associated with the two relays, K3300 and K3301. These troubles, caused by either dirty relay contacts or broken wires, usually show up as faulty operation in 1 or more of the 3 modes of operation.

b. One method that is sometimes helpful in locating the defective relay is to tap lightly on the chassis, directly above the relay, while observing either the test meter or the A-scope for an indication. To locate the defective contact, it is usually necessary to observe the relay action while changing the position of the OPERATION SELECTOR switch S2354. Arcing will usually be present at a dirty relay contact. The proper procedure for cleaning relay contacts can be found in TM 11-1167, page 6-12.

Section II. TROUBLESHOOTING THE MTI SYSTEM

61. SIGNAL COMPARATOR

a. As the signal comparator consists of eight separate sections (five being subassemblies), each with a definite function, it should be possible to segregate a fault without too much difficulty. As a reference the eight sections are listed as follows:

- 60-mc if amplifier (subassembly)
- Coho (coherent oscillator) (subassembly)
- MTI repetition rate trigger amplifier (main chassis)
- Delay amplifier (subassembly)
- Nondelay amplifier (subassembly)
- Delay network (subassembly)
- Balancer and amplifier (main chassis)
- Gate generator (main chassis)

b. When normal radar reception is in use, only the 60-mc if amplifier and part of the balancer and amplifier circuits are involved. When gated MTI is in use, these sections plus the remaining sections are involved.

c. It follows that if trouble is encountered on both MTI and normal radar operation, there is a good likelihood of the trouble being in the 60-mc amplifier, in the balancer and amplifier, or in the power supply for these sections. If the trouble is present only on MTI, the remaining sections then should be investigated.

d. The test meter of the unit provides a check of the output levels of the 60-mc if amplifier, coho, repetition rate trigger amplifier (DELAY LINE INPUT position), nondelay amplifier, and delay amplifier. Therefore, measurements taken of these circuits, by the use of the test meter and TEST SELECTOR switch, provide an indication of possible fault in a particular section.

e. The delay network can be checked for maximum attenuation by substituting the test attenuator (mounted on fuse clips above the unit chassis) for the network. The test procedure is given under paragraph 35b. In taking the measurements mentioned in the preceding

paragraph, the network is checked for passage of signals by the DELAY LINE INPUT and NON-DELAY AMPL OUT positions of the TEST SELECTOR switch. Although the output of the delay network is checked at the delay amplifier output, the delay amplifier can be eliminated when the check is made with the test attenuator. Of course, no signals with either the test attenuator or the delay network in the circuit would indicate a fault in the delay amplifier.

f. Another indication of possible trouble in the delay network is a check of triggers developed by the repetition rate trigger amplifier. If a fault exists in the delay network, the output triggers may be affected because the network is part of the trigger generating circuit as well as part of the signal delay circuit. The triggers can be checked by an oscilloscope at J302, provided that a 75-ohm resistor is connected across the test leads. In this instance the oscilloscope is used as a synchroscope, with the SWEEP SPEED control set at START-STOP.

g. After a defect is localized to a particular section of the unit, tube voltage and circuit checks should reveal the source of trouble. Actually, a major portion of the signal comparator circuits are straight forward. For example, the 60-mc if amplifier and also the delay and nondelay amplifier circuits are standard arrangements found in most broadband if amplifiers.

h. Perhaps the most important factor in servicing the signal comparator is a good knowledge of the functioning of all circuits. A thorough study of the theory of signal comparator operation is recommended.

Section III. MTI ALINEMENT

62. GENERAL

Throughout the text, emphasis has been placed upon the alinement of the MTI circuits. The only reference that has been made in the previous chapters was concerned with only the channels of MTI and an overall procedure of alinement has not been given. The steps that are included in the text must be accomplished in an accurate manner and care must be taken with each step, in order to insure the best cancellation of fixed targets and detection of moving targets.

63. MTI ALINEMENT

(1) Energize the equipment and allow a one-half hour warmup period before making adjustments.

(2) Using a 20, 000 ohms-per-volt voltmeter, measure the following voltages on E401 of the power supply unit. If necessary, adjust the indicated adjustment controls to obtain the specified voltage.

E401 Terminal	Voltage	Adjustment
4A	+300 v	R433
1A	+150 v	R416
5A	+450 v	None
6A	-150 v	None

(3) Tune the receiver for maximum signals, using the LO MOTOR control (indicator unit).

(4) At the signal comparator, red line the meter readings, following the instructions on the front panel.

NOTE. The IF AMPL LEVEL should be red lined with RADIATE (indicator unit) OFF.

(5) Peak tune for maximum signals, by adjusting capacitor C305 (60 mc if chassis in signal comparator).

NOTE. Adjustment of C305 may change the IF AMPL LEVEL. After adjusting C305, the IF AMPL LEVEL control should be readjusted for a red line meter reading with RADIATE (indicator unit) OFF.

(6) At the signal comparator, set the TEST SELECTOR to (5) AMP BALANCE and the OPERATION SELECTOR to REMOTE. Adjust the MTI AMPLITUDE BALANCE control on the indicator for a red-line reading on the signal comparator TEST METER.

(7) Adjust CARRIER GATE LENGTH control R1365 (signal comparator chassis) in a clockwise direction until the magnetron current, observed on the MAGNETRON CURRENT meter of the receiver-transmitter, suddenly drops to about 30 milliamperes. Slowly adjust R1365 in a counterclockwise direction until the magnetron current jumps to 40 milliamperes or more.

(8) Vary the MTI AMPLITUDE BALANCE control on the indicator, and observe the MAGNETRON CURRENT meter on the receiver-transmitter. The magnetron current should suddenly drop by 2, or more, milliamperes, indicating that the MTI trigger is locked in. If the MTI trigger is not locked in, repeat steps (6) and (7) above, until the MTI trigger is locked in.

(9) At the indicator, set the OPERATION selector to GATED MTI and the MTI RANGE GATE at 0 (maximum counterclockwise). Rotate the antenna and select a good, solid clutter pattern. Stop the antenna on the solid clutter pattern. Set COHO SYNC control R2355 (signal comparator front panel) to its maximum counterclockwise position, set the OPERATION selector of the indicator to COHO ADJ and remove P304 from receptacle J304 (signal comparator front panel).

(10) Slowly adjust capacitor C361 (COHO IF chassis of the signal comparator) while carefully observing the pattern on the A-scope. The changing pattern will be dividing into wider blocks of signal, going from or toward the left-hand edge of the baseline. That is, the signals will appear to be moving toward or away from the start of the baseline. At the exact point where the coho oscillator frequency matches the 60-mc coho sync pulse (zero beat), the signals will suddenly reverse their apparent direction of movement. Set C361 to the zero beat point. Reconnect P304 to J304 (removed in step (9) above). If it is desired to use tuned cavity TS-172B/UP (echo box) to adjust C361, connect the test cable supplied with the echo box from the echo box to receptacle J501 of the receiver-transmitter. Set the TUNE-READ RINGTIME switch

of the echo box to the TUNE position and adjust the frequency dial for maximum meter indication. A pattern of square waves will be observed on the A-scope of the indicator. Adjust C361 in the direction to decrease the number of square waves appearing on the A-scope. At the exact point where the coho oscillator frequency matches the 60-mc coho sync pulse (zero beat) the pattern will drop to a straight baseline. If C361 is adjusted beyond the zero beat point, the amplitude and frequency of the square waves will increase. It will be noted that the apparent polarity of the square waves changes when passing through the zero beat point. Set C361 to the zero beat point. Reconnect P304 to J304 (removed in step (9) above).

(11) At the indicator, set the OPERATION selector to NORMAL VIDEO and adjust the RECEIVER GAIN control for approximately $\frac{1}{4}$ inch grass as observed on the A-scope. Set the A-scope VIDEO GAIN control fully counterclockwise, then adjust slowly in a clockwise direction to obtain maximum signal amplitude, at the point where further rotation does not increase signal amplitude but does increase noise level. Back off on the control until the signals are at maximum amplitude.

(12) Set the OPERATION selector of the indicator to GATED MTI, the MTI RANGE GATE control to 80, and the A-scope RANGE SELECTOR to 160. Adjust GATE BALANCE control R3328, on the signal comparator front panel, for a straight baseline of the trace observed on the A-scope. Check the setting of R3328 by varying the MTI RANGE GATE control through its entire range (0 to 160). The baseline should be straight at all positions of the control.

(13) Set the A-scope RANGE SELECTOR to 20 or 40 and the MTI RANGE GATE control fully clockwise (160). Alternately adjust the MTI TIME BALANCE controls on the indicator for the best possible cancellations of fixed targets. Adjust the controls carefully, repeating each adjustment many times.

(14) Adjust COHO SYNC control R2355, on the front panel of the signal comparator, for maximum cancellation with stability of pattern. Set the MTI TIME BALANCE control of the indicator to its midposition and adjust capacitor C1353 on the signal comparator for maximum cancellation. Readjust the MTI TIME BALANCE control of the indicator for maximum cancellation (little adjustment should be necessary).

(15) Adjust NON-DELAY AMPL OUT control R2353 (signal comparator front panel) and the MTI AMPLITUDE BALANCE control (indicator) for maximum cancellation with stability of pattern, as observed on the A-scope. It will be noted that as each control is slowly varied, a distinct dip is observed in the clutter. However, the optimum setting should not cause the meter readings to deviate from the red line (observed on the signal comparator TEST METER) by more than 1/8 inch. Readjust the MTI TIME and AMPLITUDE BALANCE controls at the indicator for maximum cancellation.

(16) Slowly readjust CARRIER GATE LENGTH control R1365 (signal comparator chassis) for the best cancellation with stability of pattern. Move the control slowly, stopping to observe results, readjust the MTI BALANCE controls repeatedly. The optimum setting is the point at which flaming (instability of pattern) is reduced to a minimum or is completely eliminated.

(17) Readjust the COHO SYNC control (signal comparator) for maximum cancellation with stability of pattern.

(18) Readjust the VIDEO GAIN control at the indicator, following the procedure given in step (11) above.

(19) Readjust the MTI BALANCE controls at the indicator.

(20) If excellent MTI results cannot be obtained following the above procedure, see the following paragraph for possible troubles.

Section IV. MTI MAINTENANCE

64. FACTORS AFFECTING MTI OPERATION

Assuming that the signal comparator and the quartz delay line are operating normally, the following factors will affect MTI operation.

Local oscillator (2C40) frequency instability.
Arcing in any part of the rf system.
Magnetron frequency instability, arcing, pulling.
Primary power form factor.
Excessive ripple on voltages delivered from power supply.
Improper MTI alinement.
Weather conditions.
Improper values of regulated voltages.

65. LOCAL OSCILLATOR FREQUENCY INSTABILITY. (2C40 tube)

Frequency drift of the 2C40 tube can readily be noted by poor cancellation or unstable pattern as viewed on the A-scope when OPERATION SELECTOR of signal comparator is set to COHO ADJUST position. After carefully alining the MTI following the procedure given in paragraph 60, if the cancellation is not complete, the 2C40 tube can be suspected. To check the 2C40 tube stop the antenna on the most distant fixed targets available. If the cancellation of close-in targets is complete but targets further out on the A-scope do not completely cancel, the 2C40 tube is probably drifting in frequency. When observing the pattern on the A-scope with the indicator OPERATION selector in COHO ADJ, the pattern will normally fluctuate up and down at a random rate, sometimes locking in solidly for several seconds. However, if the pattern fluctuates at a very rapid rate and the locking in is not noted, and, if the pattern changes continually, the 2C40 tube is drifting in frequency and must be checked. To check the frequency stability of the 2C40 tube, proceed as follows:

a. Connect tuned cavity TS-172B/UP (echo box) to rf test jack J501. Set the MAGNETRON TUNING dial (receiver-transmitter) at about 550. Tune the echo box to obtain the magnetron frequency. This frequency must be slightly more than 60-mc below the highest mc reading obtainable on the echo box. Note this frequency on the echo box dial.

b. Connect the echo box to either the signal or coho cable from the local oscillator using the special adapter available with the TS-172B/UP echo box. (P515 signal cable; P510 -- coho cable.) Tune the receiver so that the signals are received with the receiver tuned 60-mc above the magnetron frequency.

c. Slowly tune the echo box in the vicinity of the echo box dial reading which is the sum of the reading obtained in a above, plus 60-mc.

d. Peak the reading obtained and observe the echo box meter for at least 10 minutes. During this time the 2C40 frequency should drift only very slightly. If it drifts rapidly or fluctuates so that the echo box must be continually retuned, the 2C40 tube must be replaced and the new tube checked in a similar manner.

The extreme importance of selecting a stable 2C40 tube cannot be overemphasized. The more stable the frequency of the tube, the better cancellation will be gained, which, with the resultant decrease in grass level, will allow a greater advancement of the MTI video gain, resulting in a greater sensitivity of the system when operating on MTI.

66. ARCING IN RF LINES, PEDESTAL OR ANTENNA

a. It is of extreme importance that no arcing occurs in the entire rf system. If arcing occurs, the resultant impedance mismatch will cause the magnetron frequency to vary from pulse to pulse so that the proper phase relationship cannot be maintained and the MTI cancellation will suffer.

b. All rf lines should be regularly examined for signs of arcing. Arcing most often occurs because the rf lines were not securely tightened with the strap wrench. Before assembling any rf line, observe that the rubber gaskets are firmly in place. Clean off any arc pits that might have occurred, using crocus cloth (do not use crocus cloth excessively). When joining the two sections, be certain that the two pieces fit snugly into each other before the collar is tightened. Use considerable force to tighten the lines as they must be tight.

c. Another source of arcing is in the flexible coaxial cable (RF854), where arcing sometimes occurs at the plug end of the cable. Arcing here can be readily noted as the temperature of the metal portion of the cable must never be warmer than the flexible coaxial cable itself. The flexible coaxial cable should always be slightly warmer than the metal plug ends. If the metal plug ends are warmer than the coaxial cable, arcing is present and the cable must be repaired or replaced.

d. Arcing can also occur in the pedestal at the lower end of the rotating joint (RF752) if the slipring fingers become fouled with oil, water or graph-alloy dust from RF856. At certain intervals, the entire pedestal should be inspected. RF752 should be removed, and the slipring fingers pulled out using the special tool required. The pedestal should then be inspected, cleaned, burnished and reassembled.

e. If RF752 is not properly centered in the pedestal, RF856 (upper-rotating joint) will not readily match up so that the graph-alloy portion will fit under the fingers of RF752. Care should always be taken that RF752 is accurately centered. This is necessary to prevent arcing and undue wear or damage to either RF752 or RF856.

f. Water in the rf lines, resulting from leakage or excessive condensation, will result in serious arcing, often sufficiently severe to operate the protective relay. The corrosive action of the arc, breaking down the water and forming a corrosive acid, will rapidly destroy the plating of the rf lines. If excessive condensation is noted, check that both blower motors (B701 and B702) are operating, that the air entrance plates on the servoamplifier are removed and that the pedestal is canvas covered to protect it from direct rain if it is located where it is exposed to weather. Defective or missing rubber gaskets could allow rain and dew to enter the rf lines.

g. Extreme care must be taken to securely tighten all rf lines as once an rf line arcs, the resultant pitting of the contact surface makes it difficult to tighten the lines so that future arcing will not occur.

67. MAGNETRON FREQUENCY INSTABILITY

a. If the magnetron is properly aged using a variac, its frequency stability is usually excellent. As with all variable frequency magnetrons, it is possible to tune them to an unstable point, which may occur at one or more places over its entire tuning range. A slight change in magnetron frequency should result in stable operation.

b. It has been noted that magnetrons which have not been properly aged, will often act very erratically when set to below 5 on the magnetron tuning dial. If it is necessary to use a magnetron without sufficient aging, always operate the magnetron in the frequency spectrum which results in minimum operation of the protective relay.

c. To check the frequency stability of the 5J26 magnetron, connect the echo box to the rf test jack (J501) and tune the echo box for maximum dial reading. Observe this reading for at least ten minutes. During this time the magnetron may drift slightly but its drift should be very slow and always in the same direction. Rotate the antenna at various speeds and observe if the magnetron frequency changes at any portions of the 360° rotation. If it does, there are two possible causes for this; arcing in the RF752 rotary joint or magnetron pulling.

(1) Arcing in the rotary joint will cause a mismatch to the magnetron which will result in the magnetron changing frequency while the arcing occurs. The remedy is to check the rotary joint as described in paragraph 66.

(2) Magnetron pulling occurs when the radar set is so located that large buildings, steel towers, hill, etc., are very near the antenna. When the magnetron fires, a large burst of energy is radiated. These nearby objects will reflect a high level of returned energy back into the magnetron before it has completed its cycle, causing a mismatch to the magnetron with the resultant change in frequency. The only remedy for this is to change the site location, if possible.

d. With the antenna rotation off, if it is noted that the magnetron output varies rapidly (as viewed on the echo box meter), this is usually a sign of arcing in the rf lines. If this flickering is noted, set the TRIGGER switch at the modulator to INTERNAL and observe the echo box meter. If the reading is then stable, the faults may be in the signal comparator.

If this flickering occurs on both EXTERNAL and INTERNAL trigger (it will usually be more pronounced when on INTERNAL trigger), the source of arcing will have to be located and remedied. Arcing in RF854 is a common cause of this trouble.

68. PRIMARY POWER FORM FACTOR

With different prime power voltage shapes, the output of the modulator will vary from one power unit to the next even though the line voltage and frequency are the same. To overcome the influence of the line form factor, the following procedure should be used:

a. Adjust the engine speed for proper output voltage and frequency. Under no circumstances should the line voltage be in excess of 121 volts or the line frequency below 385 cycles. High-line voltage can cause synchro failures and also poor regulation of the B-plus voltages.

b. If the vibrating reed frequency meter shows a continual change in frequency or if the line voltage drops much below 115V ac, the gasoline engine must be adjusted, repaired or replaced. Normal MTI operation cannot be obtained if the line voltage or frequency is fluctuating.

c. Adjust the primary taps on T151 in the modulator until the magnetron current is as close to 42 milliamperes as obtainable, at least 40 milliamperes. At no time should the magnetron current exceed 46 milliamperes.

69. EXCESSIVE DC VOLTAGE RIPPLE

Excessive ripple will modulate the dc voltage so that the phase relation from pulse to pulse will not be the same. This will cause the MTI cancellation to suffer noticeably as a flutter of the canceled fixed targets. These ripple voltages should be checked regularly and, if not within tolerance, the filtering circuits, ground connections, etc., must be checked until the ripple is well within the tolerances given. Using a vacuum-tube voltmeter, measure the ripple of the voltages listed below. The voltages are measured at E401 of the power supply. The input voltage must be stable for this check.

E401 Terminal	Voltage	Ripple Tolerance
1-A	+150 b	0.04 v
4-A	+300 v	.075 v
5-A	+450 v	6 v
6-A	-150 v	.075 v

To avoid much unnecessary work, always be certain that the radar system has been carefully alined following the MTI alinement procedure (preceding paragraph) before considering that the trouble is in the local oscillator, magnetron, arcing rf lines, etc.

70. WEATHER CONDITIONS

It has been repeatedly noticed that rain clouds, snow and certain other type clouds will affect the apparent efficiency of the MTI circuits. Such weather interference can readily be noted as a different clutter pattern on the PPI screen when viewed on normal operation. On the A-scope, certain banks of apparent targets will flutter up and down rapidly when the targets are viewed on normal operation. When on MTI, the subclutter will be considerably increased in the direction of the cloud, snow or other weather interference, making it appear that the MTI is out of alinement. After checking the alinement, if the condition continues, there is no remedy for it. Do not use the antijam feature to attempt to eliminate this or other type of interference unless you are actually being radar jammed. NOTE: Except in very unusual cases a moving target can be readily tracked through the clutter caused by the weather conditions as the response from a moving target will normally be much greater than that received from the unusual weather formation.

71. IMPROPER VALUE OF REGULATED VOLTAGES

Proper MTI operation requires the regulated voltages to be accurately adjusted. Unless the voltmeter used is known to have an excellent accuracy, always double check the adjustments with a second meter, if available.

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